Volume LXXII Number 1

THE BOTANICAL GAZETTE

Editor: JOHN M. COULTER

JULY 1921

Respiration of Dormant Seeds. Contributions from the Hull Botanical Laboratory 282 - - - - - - - - Hope Sherman 1
(With four figures)

Leaves of the Helobieae - - - - - - - - Agnes Arber 31
(With Plate I)

Notes on New or Rare Species of Rusts - - - - - W. H. Long 39

Briefer Articles
Helmut Bruchmann - - - - - - - Charles J. Chamberlain 45
(With portrait)

Current Literature
Book Reviews - - - - - - - - - - - - 48
Notes for Students - - - - - - - - - - - - 51

The University of Chicago Press
CHICAGO, ILLINOIS, U.S.A.

THE CAMBRIDGE UNIVERSITY PRESS, *London*
THE MARUZEN-KABUSHIKI-KAISHA, *Tokyo, Osaka, Kyoto, Fukuoka, Sendai*
THE MISSION BOOK COMPANY, *Shanghai*

CONGRESS LIBRARY JUL 25 1921 1

Volume LXXII Number 1

THE BOTANICAL GAZETTE

A MONTHLY JOURNAL EMBRACING ALL DEPARTMENTS OF BOTANICAL SCIENCE

EDITED BY

JOHN M. COULTER

With the assistance of other members of the botanical staff of the University of Chicago

Issued July 16, 1921

The Botanical Gazette is published monthly by the University of Chicago at the University Press, 5750 Ellis Avenue, Chicago, Ill. ¶The subscription price is $9.00 per year; the price of single copies is 75 cents. Orders for service of less than a half-year will be charged at the single-copy rate. ¶Postage is prepaid by the publishers on all orders from the United States, Mexico, Cuba, Porto Rico, Panama Canal Zone, Republic of Panama, Bolivia, Colombia, Honduras, Nicaragua, Peru, Hawaiian Islands, Philippine Islands, Guam, Samoan Islands, Shanghai. ¶Postage is charged extra as follows: For Canada, 35 cents on annual subscriptions (total $9.35), on single copies, 3 cents (total 78 cents); for all other countries in the Postal Union, 84 cents on annual subscriptions (total $9.84), on single copies, 11 cents (total 86 cents). ¶Patrons are requested to make all remittances payable to The University of Chicago Press in postal or express money orders or bank drafts.

The following are authorized to quote the prices indicated:

For the British Empire: The Cambridge University Press, Fetter Lane, London, E.C. 4, England. Yearly subscriptions, including postage, 64*s.* each; single copies, including postage, 5*s.* 6*d.* each.

For Japan and Korea: The Maruzen-Kabushiki-Kaisha, 11 to 16 Nihonbashi Tori Sanchome, Tokyo, Japan. Yearly subscriptions, including postage, Yen 19.75 each; single copies, including postage, Yen 1.75 each.

For China: The Mission Book Company, 13 North Szechuen Road, Shanghai. Yearly subscriptions, $9.00; single copies, 75 cents, or their equivalents in Chinese money. Postage extra, if mailed direct outside of Shanghai, on yearly subscriptions 84 cents, on single copies 11 cents.

Claims for missing numbers should be made within the month following the regular month of publication. The publishers expect to supply missing numbers free only when losses have been sustained in transit and when the reserve stock will permit.

Business correspondence should be addressed to The University of Chicago Press, Chicago, Ill.

Communications for the editor and manuscripts should be addressed to the Editor of the BOTANICAL GAZETTE, The University of Chicago, Chicago, Ill.

Contributors are requested to write scientific and proper names with particular care, to use the metric system of weights and measures, and in citations to follow the form shown in the pages of the BOTANICAL GAZETTE.

Papers in excess of thirty-two printed pages are not accepted unless the author is willing to pay the cost of the additional pages, in which case the number of the pages in the volume is correspondingly increased.

Illustrations are furnished without cost to author only when suitable originals are supplied A copy of the suggestions made in the January number, 1907, will be sent on application. It is advisable to confer with the editors as to illustrations required in any article to be offered.

Separates, if desired, must be ordered in advance of publication. A table showing approximate cost of separates is printed on an order blank which accompanies the proof; a copy will be sent on request.

Entered as second-class matter August 21, 1896, at the Post-Office at Chicago, Illinois, under the Act of March 3, 1879.

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on July 15, 1918.

The University of Chicago

Nature-Study Series

By ELLIOT R. DOWNING

Associate Professor of Natural Science in the School of Education of the University of Chicago

Already Published

A Field and Laboratory Guide in Biological Nature-Study

Paper covers, loose leaf, $1.50; postpaid $1.60

Intended for the use of students who are preparing to teach, and of teachers themselves. Deals with those groups of plants and animals that are of most interest to pupils.

"It gives specific suggestions and directions for field work. There are three keys: to autumn weeds, to trees, and to birds. There is much data as to methods given throughout the book, the outcome of years of work, which, brought together as it is under one cover, is invaluable to the inexperienced teacher."—*School Science and Mathematics* for May, 1919.

A Source Book of Biological Nature-Study

Cloth, $3.00; postpaid $3.20

The material is organized with special reference to the training of the teacher and the presentation of the subject to the pupil. In all the varied uses to which it may be put the 338 sketches and photographs add greatly to its effectiveness and charm.

"One fact strikes us with overwhelming force—namely, how immense an array of valuable and instructive matter can be presented to the student without a trace of dullnes or pedantry . . . . the volume is literally a moving picture of natural history and a wide open door to vaster and more comprehensive fields of research."—*Chicago Daily News* for June 4, 1919.

A Field and Laboratory Guide in Physical Nature-Study

Paper cover, loose leaf, $1.50; postpaid $1.60

The author has used the material here presented with his teacher-training classes for many years.

The Chapter Headings Are:

INTRODUCTION
COMMON MINERALS AND ROCKS
THE STARS AND OUR SOLAR SYSTEM
SOME TOYS THAT WORK BY AIR
TOP, SLING, AND BOW
THE HOT AIR BALLOON AND SOME EXPERIMENTS TO SHOW HOW IT WORKS
SOME COMMON APPLIANCES THAT OPERATE BY HEAT
MAGNETIC AND ELECTRIC TOYS
THE CAMERA, TELESCOPE, MAGIC LANTERN, AND SOME EXPERIMENTS IN LIGHT
THE HOME-MADE ORCHESTRA
HOW TO MAKE THE TELEPHONE AND PHONOGRAPH
HOW TO MAKE A PAIR OF SCALES AND USE OTHER MECHANICAL CONTRIVANCES

"It should be in the hands of every teacher in the land who has to do with seventh and eighth grades or with high school physics."—*Nature-Study Review* for April, 1920.

Other Volumes are in Preparation

Address Correspondence to

THE UNIVERSITY OF CHICAGO PRESS

5822 Ellis Avenue **Chicago, Illinois**

Cambridge University Press

The Classification of Flowering Plants. By ALFRED BARTON RENDLE, M.A., D.Sc., F.L.S., Keeper of the Department of Botany, British Museum. Vol. I. Gymnosperms and Monocotyledons. Demy 8vo. With 187 illustrations. $5.00. Cambridge Biological Series.

A Manual and Dictionary of the Flowering Plants and Ferns. By J. C. WILLIS, M.A., Sc.D. Fourth edition. Crown 8vo. $8.80. Cambridge Biological Series.

Agriculture in the Tropics. An elementary treatise. By J. C. WILLIS, M.A., Sc.D. Second edition, revised. With 31 plates. Demy 8vo. $4.40. Cambridge Biological Series.

The Elements of Botany. By SIR FRANCIS DARWIN, Sc.D., M.B., F.R.S., Fellow Christ's College. Second edition. With 94 illustrations. Crown 8vo. $2.60. Cambridge Biological Series.

Practical Physiology of Plants. By SIR FRANCIS DARWIN, Sc.D., F.R.S., and E. HAMILTON ACTON, M.A. Third edition. With 45 illustrations. Crown 8vo. $2.40. Cambridge Biological Series.

Botany. A textbook for Senior students. By D. THODAY, M.A., Lecturer in Physiological Botany and Assistant Director of the Botanical Laboratories in the University of Manchester. Revised and enlarged edition. With 230 text-figures. Large crown 8vo. $3.00.

The Ferns of South Africa containing descriptions and figures of the ferns and fern allies of South Africa. By THOMAS R. SIM. Second edition. With 186 plates. Demy 8vo. $10.00.

Mendel's Principles of Heredity. By W. BATESON, M.A., F.R.S., V.M.H., Director of the John Innes Horticultural Institution. Third impression with additions. With 3 portraits, 6 colored plates, and 38 figures. Royal 8vo. $6.00.

Herbals. Their Origin and Evolution. A chapter in the history of botany, 1470–1760. By AGNES ARBER, D.Sc., F.L.S., Fellow of Newnham College, Cambridge, and of University College, London. With frontispiece, 21 plates, and 113 illustrations. Royal 8vo. $5.60.

Water Plants. A Study of Aquatic Angiosperms. By AGNES ARBER, D.Sc., F.L.S. Royal 8vo. With a frontispiece and 171 text-figures. $12.60.

Devonian Floras. A Study of the Origin of Cormophyta. By E. A. NEWELL ARBER, D.Sc., F.L.S. With a preface by D. H. SCOTT, F.R.S. Demy 8vo. With a frontispiece and 47 text-figures. $7.00.

Practical Plant Biochemistry. By MURIEL WHELDALE ONSLOW. Royal 8vo. $6.00.

Published by the Cambridge University Press (England)
The Macmillan Co., Agents in the United States
64 and 66 Fifth Avenue, New York City

VOLUME LXXII NUMBER 1

THE

BOTANICAL GAZETTE

JULY 1921

RESPIRATION OF DORMANT SEEDS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 282

HOPE SHERMAN

(WITH FOUR FIGURES)

Introduction

Plant physiologists have long been interested in the physiological processes associated with the development and particularly with the germination of seeds. Much attention has been devoted to those seeds which, when ripe, fail to respond to germinating conditions unless subjected to special treatment or permitted to undergo a distinct rest period. Such dormant seeds offer many problems to pique the curiosity of the investigator, and work on individual seeds has given some conception of the environmental factors influencing dormancy (**4, 15, 17, 40**), as well as of the internal conditions retarding germination and of the chemical changes which take place in after-ripening (**19, 25, 27, 38**). Furthermore, dormant seeds often retain their viability for long periods of time. BEALE (**7, 8, 24, 41**) reported that *Amaranthus retroflexus* will remain viable in the ground for thirty years. If such seeds are fully imbibed, their remarkably prolonged viability may be due either to especially large food reserves or to a tremendous reduction of the rate at which such reserves are respired. A study of the respiration of stored seeds at different time intervals might help to interpret this point.

While the respiration of most plant parts has been studied more or less, there are comparatively few data on resting seeds. For this reason the study of the respiration of seeds would be of interest, per se, and if dormant seeds were selected, it might be possible both to discover differences in the respiration of related and of unrelated species, and, through the acquisition of information upon the rapidity with which food reserves were utilized, to arrive at some idea of the probable longevity of the seeds.

Most dormant seeds belong to one or another of certain main classes (CROCKER 14): those in which the dormancy is due to coat characters, as impermeability to water or to oxygen, acting in conjunction with some physiological character in the embryo aside from actual dormancy; or those in which dormancy is conditioned by the embryo itself, either through lack of differentiation or through the absence of some factor essential for germination, even when the naked embryo is exposed to all ordinary external germination conditions. In addition there are certain seeds with mature embryos whose coats apparently exclude neither water nor oxygen, but still germination is hindered; such delay in *Alisma Plantago* (15) is due to the inability of the embryo to overcome the mechanical resistance to expansion offered by the coats. Finally, dormancy may result from the joint action of two or more of these factors.

In the investigation, some of the results of which are embodied in this paper, the original intention was to study the respiration of each type of dormant seeds, but during the progress of the work the comparative respiration of dormant seeds has become of prime interest, and this phase forms the subject of the present report.

The seeds selected were three on which physiological studies had already been made, but for which respiratory data were lacking, namely, *Amaranthus retroflexus*, *Chenopodium album*, and *Crataegus*,[1] and in addition (because of their economic importance and the ease with which they could be obtained, as well as because of their relationship to *Crataegus*) seeds of the common drupaceous Rosaceae. In *Crataegus* and *Amaranthus* some attempt has been made to determine variations in respiration accompanying after-

[1] The species chiefly studied was *C. coccinea*.

ripening or aging. Furthermore, since many workers claim that catalase activity varies with the respiration, catalase determinations have been made on most of the seeds used.

Methods

Catalase activity was measured by the volume of oxygen set free from hydrogen peroxide (the Oakland Chemical Company's dioxogen) by a given weight of seeds. The apparatus was essentially that described by APPLEMAN (1), and the routine procedure was to grind the seeds for one minute in a mortar with sand and calcium carbonate, add 5 cc. of distilled water, and grind a second minute. The contents of the mortar were then transferred to a bottle which was placed in a water bath at 25° C. The level of the gas burette was adjusted, and after sufficient time had elapsed for the seed suspension to come to the temperature of the bath, the exit of the gas burette was closed. Constancy of level of the water meniscus in the gas burette was assumed to indicate stability of temperature. Thereupon the cock of the dropping funnel was opened on the minute, and 5 cc. of dioxogen was allowed to flow into the bottle, which was immediately set shaking. Readings of the volume of oxygen liberated were taken on the gas burette every minute for the first five minutes and on the tenth minute also.

The respiration determinations were made by means of a respirometer designed by CROCKER (26). This consists of a cylindrical glass chamber fitted with a glass stopper through which pass two tubes, one a manometer and the other a short, straight tube provided with a stopcock by which the chamber can be closed to the surrounding air. Seeds which had been soaked for twenty-four hours and thereafter stored on moist filter paper at about 10° C. were placed in a porcelain hooded holder, designed by HARRINGTON (25). This holder was supported within the respirometer on projections from its wall about 1 cm. above the base. The respirometer was placed in a water bath at constant temperature, and after half an hour the mercury in the manometer was brought to a level and the stopcock closed. When the experiment was to be brought to an end, the difference between the mercury levels in the two arms of the manometer was measured, and a known volume of caustic potash was introduced into the

respirometer through the stopcock tube. The potassium hydroxide was allowed to flow down the sides of the respirometer, the hood of the seed holder preventing its coming into contact with the seeds. So far as possible, measurements were made and absorption carried out without removing the respirometer from the bath. A second reading of the manometer was taken after absorption of the carbon dioxide. Barometer readings were taken after closing the chamber at the beginning, and again before absorption of the carbon dioxide at the end of the experiment. From the calibration of the respirometer it was possible to calculate its volume at the beginning (corrected for the volume occupied by the seeds) and at the end, before and after carbon dioxide absorption, a correction for the volume of the absorbent added being applied in the latter case. All volumes were further corrected to absolute zero, and to 760 mm. pressure. The difference between the volumes at the end of the experiment before and after carbon dioxide absorption represents the volume of carbon dioxide eliminated by the seeds, while the difference between the volume at the beginning of the experiment and that after absorption represents the volume of oxygen taken up by the seeds. These relations are expressed by the following formulae, which were used for the calculation:

Let $V_r \equiv$ volume of respirometer,
$V_s \equiv$ volume of imbibed seeds,
$V_a \equiv$ volume of absorbent (KOH) used,
$T_1 \equiv$ initial absolute temperature,
$T_2 \equiv$ final absolute temperature
$B_1 \equiv$ initial barometric pressure,
$B_2 \equiv$ final barometric pressure,
$m_1 \equiv$ initial manometer reading,
$m_2 \equiv$ final manometer reading.

A: $$(V_r - V_s)\frac{273}{T_1} \times \frac{B_1}{760}$$

B: $$(V_r - V_s)\frac{273}{T_2} \times \frac{B_1 \pm m_1}{760}$$

C: $$(V_r - V_s - V_a)\frac{273}{T_2} \times \frac{B_2 \pm m_2}{760}$$

Then

$$B-C = \text{volume of } CO_2 \text{ eliminated,}$$
$$A-C = \text{volume of } O_2 \text{ absorbed.}$$

From these volumes the respiratory quotient (CO_2/O_2) is easily calculated, as are also the milligrams of carbon dioxide eliminated and of oxygen absorbed per gram of imbibed weight per day, using 1.96 mg. as the weight of 1 cc. of CO_2, and 1.428 mg. as that of 1 cc. of O_2.[2]

[2] The application of these formulae is illustrated in the following calculation of data from an experiment on *Amaranthus:*

$V_r = 24.61$ cc. $T_1 = 25°$ C. $B_1 = 751.5$ mm. $m_1 = -9$ mm.
$V_s = 1.00$ cc. $T_2 = 25°$ C. $B_2 = 749.8$ mm. $m_2 = -65$ mm.
$V_g = 0.76$ cc.

Weight imbibed seeds = 1.3177 gm.; duration of experiment = 24 hours.

$$\begin{array}{l} 24.61 \\ -\ 1.00 \\ \hline 23.61 \times \frac{751.5}{760} \times \frac{273}{298} = 21.387 \end{array} \qquad (A)$$

$$23.61 \times \frac{740.8}{760} \times \frac{273}{298} = 21.082 \qquad (B)$$

$$\begin{array}{l} -\ 0.76 \\ \hline 22.85 \times \frac{684.8}{760} \times \frac{273}{298} = 18.862 \end{array} \qquad (C)$$

$$\text{Log. } \frac{273}{760 \times 298} = 7.081133 - 10$$

log. 23.61 = 1.373096	log. 23.61 = 1.373096	log. 22.85 = 1.358886
log. 751.5 = 2.875929	log. 740.8 = 2.869701	log. 684.8 = 2.835564
−3.081133	−3.081133	−3.081133
1.330158	1.323930	1.275583
Antilog. 1.330158 = 21.387	Antilog. 1.323930 = 21.082	Antilog. 1.275583 = 18.862

$B-C = 21.082 - 18.862 = 2.220$ cc. CO_2; $A-C = 21.387 - 18.862 = 2.525$ cc. O_2;
$CO_2/O_2 = 0.880$.

log. 2.220 = 0.346353	log. 2.525 = 0.402261
log. 1.96 = 0.292256	log. 1.428 = 0.154728
colog. 1.3177 = 0.880183	colog. 1.3177 = 0.880183
0.518792	0.437172

antilog. 0.518792 = 3.302 mg. CO_2 per gm. imbibed weight per 24 hours.
antilog. 0.437172 = 2.736 mg. O_2 per gm. imbibed weight per 24 hours.

Investigation

The material studied was as follows:

Seeds	Year of crop	Time of collection
Amaranthus retroflexus	1919	August 2–September 7, 1919
Chenopodium album	1918	January 29, 1919
Rumex crispus	1919	August 1919
Crataegus	1917	October 1917

In addition, seeds of *Prunus pumila* (from Mineral Springs, Indiana), and of *P. persica*, *P. armeniaca*, *P. Cerasus* var. *Morella*, *P. domestica* var. Blue Gage, and the red Burbank plum, obtained in the market, were also studied. All rosaceous seeds except *Crataegus* were freed at once from pulp, dried, and in most cases opened and used immediately. *Amaranthus* and *Chenopodium* seeds were stored at room temperature until used. Seeds of *Crataegus* were left at room temperature until they were removed from the carpels, when they were placed at once under germinating conditions at 10° C.

In preparation for an experiment the seeds were placed in distilled water and left in the refrigerator at approximately 10° C. for twenty-four hours. Cotton and filter paper were placed in Petri dishes and the whole sterilized in an electric oven. Before being used, the cotton was saturated with sterile distilled water. The seeds were thoroughly shaken in several portions of sterile water, and were either used at once or placed in the Petri dishes and stored in the refrigerator until needed, in order to avoid the influence on respiration of variations of temperature. By means of these precautions it was possible, to a very great extent, to prevent infection of the seeds with molds or bacteria, and at the same time to avoid the modification of respiration due to treatment with disinfectants (**36, 38, 42**). The amount of material used depended largely upon the size of the seed and of the apparatus. For *Amaranthus* and *Chenopodium*, 1 gm. of air-dry seeds was the usual amount, a weight representing approximately 1000 seeds. Corresponding numbers and weights for the other seeds were:

Seed	Number	Weight (gm.)
Rumex crispus	.....	0.5
Prunus persica	2	0.7 –1.00
Prunus domestica	2	0.7 –0.8
Prunus armeniaca	1	0.8+
Prunus Cerasus	10	0.8
Prunus pumila	10	0.8
Crataegus	50–200	0.7–3.00

With the use of large numbers of seeds, possible in the case of the small seeds of *Amaranthus*, *Chenopodium*, and *Rumex*, individual variations are abolished, and the results are probably more nearly typical than those obtained by the use of one or two seeds, where individual peculiarities would assume an exaggerated significance. From four to ten lots of seeds were run at the same time, since the variability in oxygen consumption and in carbon dioxide elimination was early evident, and it was only by running at least four experiments simultaneously, under precisely similar conditions, that variability could be limited to factors intrinsic in the seed.

The experimental temperature (with rare exceptions) was either 20° C. or 25° C., and the results are all corrected to a comparable basis. The average duration of the experiments was 24 hours. Occasionally a longer time interval was employed, but rarely a shorter, as the amounts of gas absorbed and eliminated were usually small. The average amount of carbon dioxide eliminated during an experiment was 2 cc., with a maximum of 4 cc. The volume of the respirometers was approximately 25 cc. Since KIDD (**28**) found that 10 per cent of carbon dioxide retards respiration, the accumulation of this gas during an experiment may have slightly modified at times the character of the respiration.

CATALASE DETERMINATION

Table I is a comparison of the catalase activity in the different seeds studied. The variability in catalase activity is extreme,

TABLE I

CATALASE ACTIVITY OF SEED IMMEDIATELY AFTER HARVESTING

SEEDS	WEIGHT OF MATERIAL (GM.)	CONDITION	OXYGEN (CC.) LIBERATED AFTER			
			1 minute	3 minutes	5 minutes	10 minutes
Amaranthus retroflexus	0.13	Imbibed	3.20	6.10	7.67	8.97
Chenopodium album	0.13	Imbibed	3.00	6.05	7.40	7.30
Apricot	0.13	Imbibed	10.10	35.10	48.20	56.50
Blue gage plum	0.13	Imbibed	7.90	21.40	28.80	35.60
Blue gage plum	0.13	As removed from carpel	2.65	9.93	12.68	16.55
Burbank plum	0.13	As removed from carpel	2.12	7.85	9.72	11.70
Crataegus	0.0449	As removed from carpel	4.50	10.50	14.30	18.30
Crataegus	0.0688	Imbibed	7.50	18.00	23.10	27.60

especially among the rosaceous seeds. Of these, the greatest activity occurred in apricot, 48 cc. of oxygen being liberated from hydrogen peroxide in five minutes by 0.13 gm. of imbibed seeds. The red Burbank plum had the lowest activity of any rosaceous seed, an equal weight of imbibed seeds liberating only 9.7 cc. of oxygen. In table II the catalase activity of hawthorn is given by periods from the fourth to the forty-second day, while the same

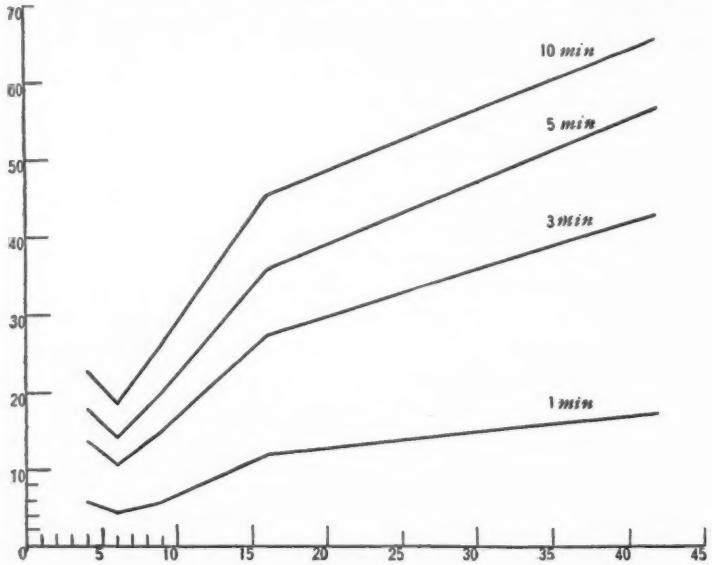


FIG. 1.—Curves of catalase activity at 1, 3, 5, and 10 minute intervals in *Crataegus:* horizontal axes represent time in days after harvesting; vertical axes represent cc. of O_2 liberated; temperature 25° C.

data are presented graphically in fig. 1. There is an increase in catalase activity as after-ripening progresses. A determination made on the after-ripened seeds, 128 days at 10° C., suggests that this increase continues after the forty-second day, but at a very slow rate. This slowness of increase was observed by ECKERSON (19) in her microchemical study of after-ripening in *Crataegus*. The stability of catalase activity in *Amaranthus* during the first month after harvesting is plain from table III.

TABLE II

CATALASE ACTIVITY IN *Crataegus* DURING DORMANCY

NUMBER OF DAYS AT 10° C.	WEIGHT OF MATERIAL (GM.)	OXYGEN (CC.) LIBERATED AFTER			
		1 minute	3 minutes	5 minutes	10 minutes
4.....	0.0410	5.8	13.7	17.9	22.9
6.....	0.0690	4.4	10.6	14.3	18.8
9.....	0.0778	5.7	15.0	20.0	26.2
16.....	0.0773	11.9	27.2	36.0	45.5
42.....	0.0791	17.3	42.9	57.0	65.8
128.....	0.1007	25.6	57.2	65.2*	67.0

*There are two possible explanations for the small increase in catalase activity from the 42nd to the 128th day: (1) the amount of oxygen liberated may have been limited by the use of only 5 cc. of dioxogen; (2) a determination should have been made at 90 days, when after-ripening was complete. After that time the seed may go into a secondary dormancy (**18**).

TABLE III

CATALASE ACTIVITY IN *Amaranthus retroflexus* (0.13 GM. IMBIBED SEEDS USED)

NUMBER OF DAYS AFTER COLLECTION	OXYGEN (CC.) LIBERATED AFTER			
	1 minute	3 minutes	5 minutes	10 minutes
8.....	3.0	6.2	7.9	9.2
16.....	2.5	5.0	6.2	7.3
28.....	3.4	6.2	7.7	9.0
44.....	3.8	7.2	8.9	10.4

RESPIRATION

Table IV embodies the comparative respiratory behavior of all ten seeds. While all but *Rumex* have a respiratory quotient less than unity, indicating an oxygen intake in excess of the carbon dioxide elimination, the value of the carbon dioxide-oxygen ratio varies within wide limits. For the Rosaceae the "respiratory intensity," as measured by the milligrams of carbon dioxide eliminated per hour per gram of imbibed seeds, averages about 0.08, while in the other seeds it is higher, being about 0.11 in *Amaranthus*, and 0.15+ in *Rumex* and *Chenopodium*. This difference may be due to the character of the storage substance, chiefly starch (**44**), present in the last three seeds, but it is undoubtedly also attributable in part to a difference in degree of dormancy.

Only one set of experiments was carried out on *Rumex*, because it was found that even immediately after harvesting the seeds would germinate. In many of the seeds the coats were ruptured and the hypocotyls emerging by the end of the experiment. *Chenopodium* also exhibited a marked readiness to germinate. *Amaranthus* was more dormant, but even within a few weeks of harvesting, on removing the seeds from the respirometer after an experiment, an occasional seed with coat broken was found; while during the later experiments, over 100 days after harvesting, the number with broken coats increased greatly (80 seeds per 1000). The

TABLE IV

RESPIRATORY VALUES (AT 25° C.)

Seeds	No. of experiments	CO_2/O_2	Mg. CO_2 per 24 hours per gm. imbibed weight	Mg. O_2 per 24 hours per gm. imbibed weight
Amaranthus retroflexus	37	0.856	2.691	2.324
Chenopodium album	14	0.928	4.213	3.307
Rumex crispus	9	1.160	3.636	2.291
Crataegus	56	0.774	1.548	1.474
Peach	14	0.675	1.881	2.033
Apricot	30	0.648	2.106	2.392
Cherry	19	0.866	2.589	2.186
Sand cherry	19	0.876	2.288	1.935
Blue gage plum	19	0.696	2.579	2.748
Burbank plum	10	0.912	1.998	1.610

rosaceous seeds are really dormant. *Crataegus* requires three months of after-ripening at low temperature (5° C. optimum) before the hypocotyl emerges from the coat. The changes occurring during after-ripening in *Crataegus* progress slowly (**19**) until very near the end of dormancy. The data reported represent determinations covering the period from the first to the seventy-seventh day under germinating conditions. At this latter time the seeds are still dormant and would fail to germinate if removed to a higher temperature. For the other rosaceous seeds no attempt was made to determine the exact duration of dormancy, although it was observed that seeds left in the refrigerator germinated in from 1.5 to 3 months.

It has been suggested (**17**) that the dormancy of *Crataegus*, although chiefly conditioned by the embryo, is in part dependent

upon the coats, which reduce the rate of imbibition and perhaps of oxygen entrance. The effect of an atmosphere entirely oxygen was accordingly determined, and it was found that the quotient and the respiratory intensity of the dormant seed still fluctuated. The mean respiratory quotient was a trifle lower than in ordinary air, 0.728 instead of 0.774. Further investigation of this point will determine the effect of varying percentages of oxygen upon the dormant seed and on the after-ripened as well. Although a detailed study of the respiration of the after-ripened seed is yet to be made, data already obtained seem to indicate that the respiratory quotient and the milligrams of carbon dioxide eliminated are

TABLE V

RESPIRATION OF *Amaranthus retroflexus* (AT 25° C.)*

Number of days after harvesting	CO_2/O_2	Mg. CO_2 per 24 hours per gm. imbibed weight	Mg. O_2 per 24 hours per gm. imbibed weight
3	0.824	2.425	2.150
11	0.850	2.263	1.938
24	0.892	2.299	1.877
35	0.890	2.932	2.417
40	0.854	1.955	1.656
71	0.877	2.705	2.591
104	0.802	4.475	4.056
140	0.885	3.979	3.500
176	0.842	1.794	1.537

* Seeds stored at room temperature until used.

slightly higher than in the dormant seed, while the oxygen absorption is lower. The effect of increased percentages of oxygen on after-ripened apple seed is to increase its respiratory intensity (**25**). It may be that this will be found to be the effect on the after-ripened hawthorn.

The values given for *Amaranthus* in table IV are averages based on experiments on seeds at intervals from 3 to 176 days after harvesting. In table V these respiratory values are given by periods, while in fig. 2 the carbon dioxide-oxygen ratio, and the respiratory intensity, as indicated by milligrams of carbon dioxide eliminated as well as of oxygen absorbed, are plotted in a time curve. The uniformity of the carbon dioxide-oxygen ratio is noticeable. The high values for the 104th and 140th days are accompanied by

a slight increase in germination. Still more interesting facts are brought out by the frequency histograms (fig. 3), from which are evident the value most frequently appearing for the carbon dioxide-oxygen ratio, and the total variation of this ratio in the entire number of experiments on each seed. In plotting these histograms the values for the quotients were grouped, and since it was found that experimentally and mathematically the digits for the quotient

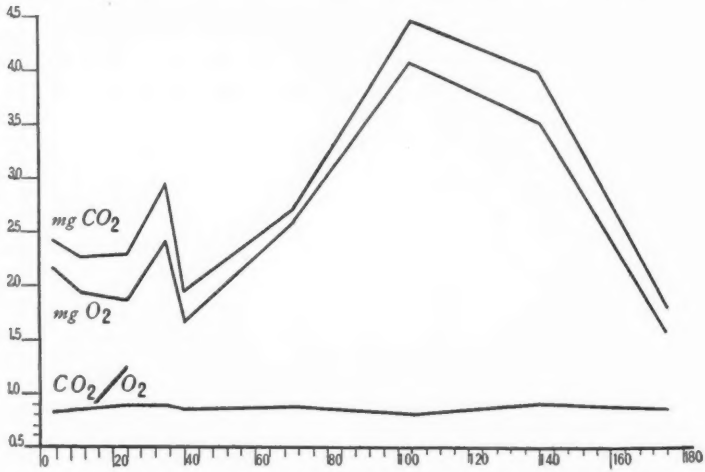


FIG. 2.—Respiration of *Amaranthus retroflexus* under storage at room temperature: horizontal axes represent time in days after harvesting; vertical axes represent values from 0.5 to 4.5 for the CO_2/O_2, these being absolute numbers indicating ratio; for "respiratory intensity" curves represent mg. of gas per gram imbibed weight of seeds per 24 hours.

are significant only to hundredths, the interval between these groups or classes was taken as 0.01.

The range of the value of this ratio, as determined by the maximum and minimum, varies widely in the different seeds, being least in *Amaranthus* (0.685–0.975, that is, 29 classes) and widest in hawthorn (0.470–1.140, that is, 67 classes). In *Chenopodium* the heaviest grouping lies within a range of only seven classes, but between the lower limit of this group and the next lowest quotient is a gap of nineteen classes, while above the group's highest limit

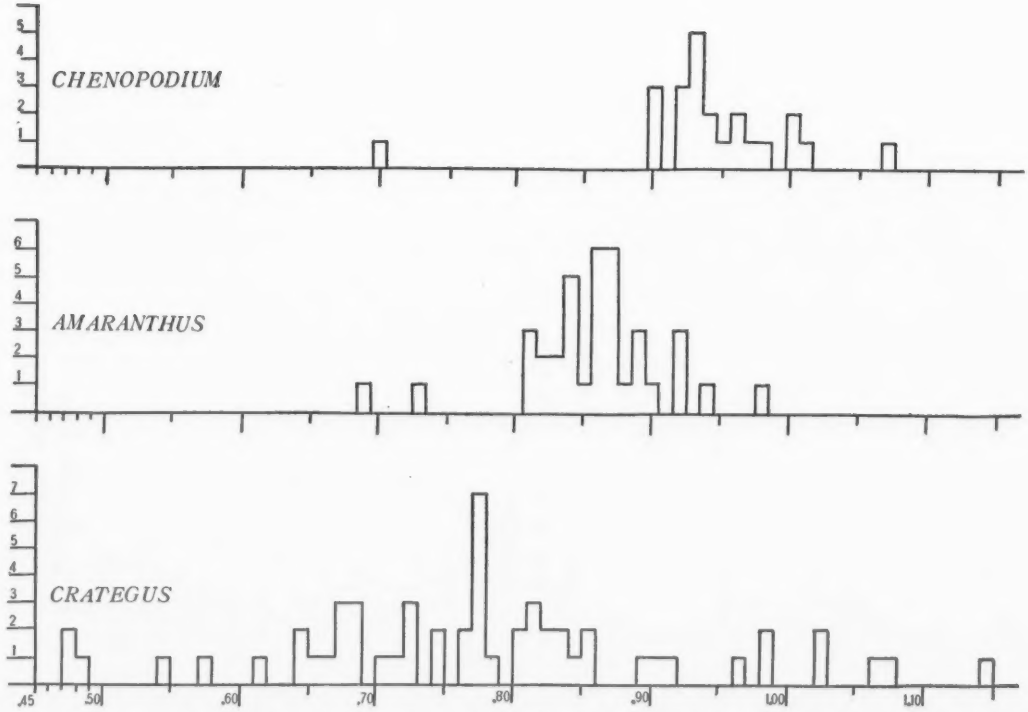


FIG. 3.—Frequency distribution of respiratory quotient in *Crataegus*, *Amaranthus*, and *Chenopodium:* horizontal axes represent class in which respiratory quotients fall; vertical axes represent number of experiments whose quotients fall in given class. Class interval for *Crataegus* 0.01 (0.47–0.48); mean 0.7905; mean deviation 0.079, hence majority of such experiments will tend to vary from 0.79 by 0.08; standard deviation 0.172. Class interval for *Amaranthus* 0.01 (0.685–0.695); mean 0.8578; mean deviation 0.04; standard deviation 0.05. Class interval for *Chenopodium* 0.01 (0.685–0.695); mean 0.9431; mean deviation 0.02; standard deviation 0.04.

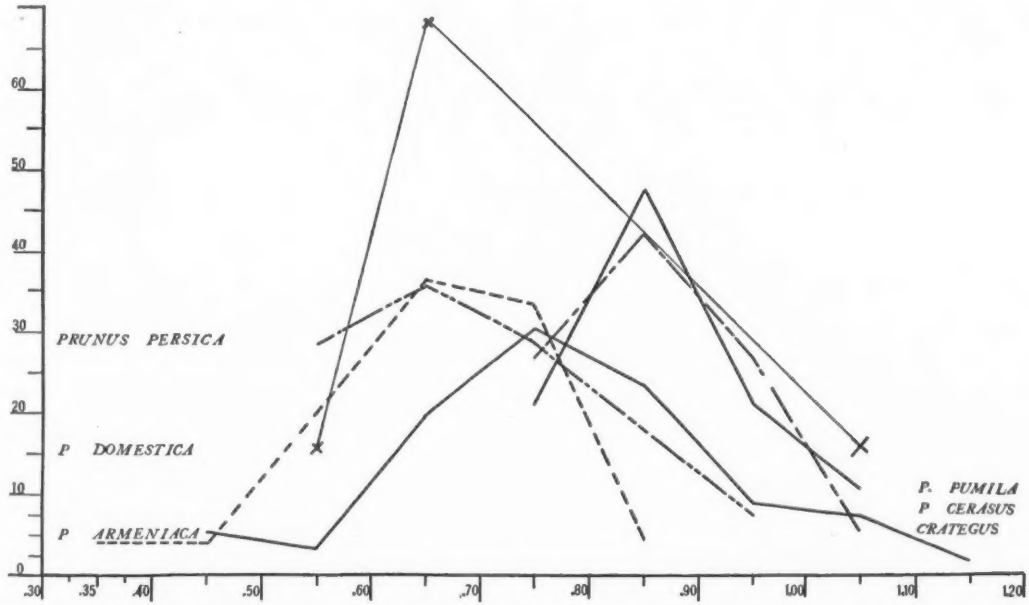


FIG. 4.—Comparison of respiratory quotients in Rosaceae; vertical axes indicate percentages of experiments in which each quotient value occurs; horizontal axes indicate quotient values; grouping is by tenths (from 0.1–0.2, etc.); maximum for peach, apricot, and blue gage plum lies between 0.6 and 0.7 CO_2/O_2 value; for hawthorn between 0.7 and 0.8; for cherry and sand cherry between 0.8 and 0.9.

are five quotients grouped discontinuously. The irregularity and discontinuity of grouping lay the extreme values open to question from the mathematician's point of view. In this instance experimental evidence supports the mathematician's feeling that certain unusual factors must be working to produce the higher values, inasmuch as these were obtained in experiments on seeds of the 1919 crop, tested within two days after their collection. The seeds were not entirely freed from chaff and adherent scales, and in each set mold developed freely during the experiment. The high values obtained, therefore, represent the joint respiratory activity of seeds and mold. These values have been allowed to stand in the histogram to illustrate the value of such treatment of data as a test of its uniformity, but they are not used in calculating the average for the type quotient in table IV.

In fig. 4 the values for the respiratory quotients of the Rosaceae are plotted in a percentage curve, the abscissas representing the value of the quotients, and the ordinates representing the percentage of the total number of experiments on each seed, in which each value occurred. The maximum percentage of the experiments with the six rosaceous seeds, apricot, peach, cherry, sand cherry, blue gage plum, and hawthorn, gives respiratory quotients lying between 0.60 and 0.90, the extreme range of the means for the different seeds (table IV) being twenty-three classes, 0.648–0.876. Within this range the maxima fall into three groups: those of cherry and sand cherry, between 0.80 and 0.90; those of peach, apricot, and blue gage plum, between 0.60 and 0.70; while that of hawthorn lies intermediate between these values (0.70–0.80). Thus the maximum for hawthorn falls very close to 0.756, the mean of the quotients (table IV) for these six seeds; and with the exception of a single value for apricot all the quotients for these rosaceous seeds lie within the range of the quotients of hawthorn.

Discussion

Increase in catalase activity during after-ripening of seeds and during germination has been reported by numerous workers. ECKERSON (19), by microchemical methods, found an increase in the activity of catalase during the after-ripening of *Crataegus*, and

in the present investigation the same phenomenon was observed macroscopically, under after-ripening and germinating conditions. Such an increase during after-ripening is characteristic of seeds with dormant embryos.

On the other hand, in *Amaranthus retroflexus* catalase activity appears to be far less subject to fluctuation. CROCKER and HARRINGTON (**16**) find surprisingly slight variation in the catalase activity during after-ripening, which in *Amaranthus* occurs "during the first three or four months in dry storage." The activity for the first month and a half after harvesting, as shown in table III, is maintained at a very uniform rate. A comparison of the values obtained on the imbibed seeds with those found by CROCKER and HARRINGTON for the dry powder indicates the uniformity of the degree of activity in different seeds:

WEIGHT OF POWDER (GM.)	OXYGEN (CC.) LIBERATED AFTER		
	1 minute	5 minutes	10 minutes
0.10 dry powder.....	4.9	9.0	11.1
0.13 imbibed seeds...	3.9	6.1	7.1

The values for the dry seeds, however, are slightly higher than for the imbibed, probably owing to the greater concentration of material in a given weight. In this connection the results obtained by CROCKER and HARRINGTON on samples of *Amaranthus* collected in 1894 are of interest. They found the catalase activity of these twenty-three year old seeds but little diminished, although there was complete loss of viability.

DATE OF COLLECTION	OXYGEN (CC.) LIBERATED AFTER			PER CENT GERMINATION AFTER 7 DAYS
	1 minute	5 minutes	10 minutes	
1917 (average of 3 samples).	8.3	20.0	23.8	100
1894 (average of 3 samples).	7.8	17.8	20.8	0

The extreme stability of the catalase activity is emphasized by the fact that one 1894 sample gave values identical with those obtained from one of the 1917 samples:

Date of collection	Location	Oxygen cc. liberated after			
		1 minute	3 minutes	5 minutes	10 minutes
1917.....	Pullman, Wash.	8.7	18.1	22.7	26.8
1894.....	East Lansing, Mich.	8.7	18.1	22.7	26.8

In the seeds studied in the present investigation, the greatest degree of activity was manifested by the rosaceous seeds (seeds having dormant embryos).

Many plant and animal physiologists have been inclined to postulate a parallelism between catalase activity and respiratory intensity (**2, 3, 10, 11, 12, 13**). In *Acer saccharum* (**27**) and *Juniperus virginiana* (**38**) both catalase activity and respiratory intensity increase as dormancy ends and germination begins. In *Crataegus* catalase activity increased continuously up to the twelfth day in the germinator (the time of the last determination), but the increase was not uniform. Respiratory intensity increased up to the sixth day. From that time to the seventy-seventh day it tended to decrease, but at an irregular rate and with considerable fluctuation. In *Amaranthus* the respiration, like the catalase activity, is maintained at a relatively uniform rate for some time (176 days), but fluctuations in the one are not coincident with fluctuations in the other, and at times may be in an opposite direction. These facts are in harmony with the decision to which their own studies led Crocker and Harrington, that "in *Amaranthus* seeds there is no evidence of a correlation between catalase activity and respiratory intensity."

That high catalase activity does not necessarily accompany a high respiratory quotient or respiratory intensity (as indicated by milligrams of carbon dioxide eliminated) is evident when the seeds studied are arranged in descending order of these values, as given in table VI.

Although there are relatively few determinations of respiratory values for resting seeds, the literature is rich in findings for other plant parts. A comparison of these values, however, is often difficult because of their variable form and the frequent absence of data necessary for the determination of measured and calculated values.

In table VII results selected from numerous investigations have been recast in such form as to make them comparable with the results on resting seeds obtained in the present study.

In the following discussion of the respiration studies the results are treated as they stand. It is recognized that the temperature at which the experiments were carried out (20°–25° C.) was high, and undoubtedly led to more vigorous respiration than occurs at 10° C. The transfer from the latter temperature, at which the seeds were stored when under after-ripening or germinating conditions, to the higher temperature of the water bath, may in

TABLE VI

Catalase activity	Respiratory intensity		CO_2/O_2
	Mg. CO_2 eliminated	Mg. O_2 absorbed	
1. Apricot	Chenopodium	Chenopodium	Rumex
2. Blue gage plum (imbibed)	Rumex	Blue gage plum	Chenopodium
3. Crataegus (imbibed)	Amaranthus	Apricot	Burbank plum
4. Crataegus (as removed from carpels)	Cherry	Rumex	Sand cherry
5. Amaranthus	Blue gage plum	Cherry	Amaranthus
6. Chenopodium	Sand cherry	Amaranthus	Cherry
7. Blue gage plum (as removed from carpels)	Apricot	Peach	Crataegus
8. Burbank plum	Burbank plum	Sand cherry	Blue gage plum
9.	Peach	Burbank plum	Peach
10.	Crataegus	Crataegus	Apricot

itself have accelerated respiration. In the case of apple, HARRINGTON (**25**) finds great diminution of the respiratory intensity at low temperature. An investigation of the respiratory intensity of the seeds used in the present instance for ten degree intervals of temperature will throw light on this point.

The problem of the longevity of seeds is still unsolved, although various theories have been advanced. Loss of vitality might result from exhaustion of stored food, degeneration of enzymes, accumulation in respiration or digestion of substances toxic to the seed, or from still other internal changes in the seed substance inimical to its life. GROVES (**14, 23**) found that life duration of *Triticum sativum* was a logarithmic function of the temperature, and LEPESCHKIN'S time-temperature formula for the coagulation of

TABLE VII

COMPARATIVE RESPIRATION OF DIFFERENT PLANT ORGANS

ORGAN	REFERENCE	TEMPERATURE (°C.)	CO_2/O_2	Mg. CO_2 per hour per gm. fresh (or imbibed) weight	Mg. O_2 per hour per gm. fresh (or imbibed) weight
Seedlings					
Triticum	5	13	0.98	55.92	41.54
Ricinus communis	5	20	0.96	37.67	33.54
Lupinus	22	8	1.03	36.49	25.56
Stems of succulents					
Sedum reflexum					
Large stems (day)	5	31	0.98	23.83	17.70
Large stems (night)	5	23	0.88	17.05	14.14
Opuntia tomentosa					
Very young (day)	5	25	0.77	3.86	3.83
Very young (night)	5	23	0.047	0.412	6.40
Stamens					
Antirrhinum majus					
Anthers	32	24	0.87	2.86	5.62
Filaments	32	24	1.02	1.32	2.32
Entire	32	20	0.93	0.606	0.457
Acanthus mollis					
Adolescent	32	21	0.91	1.027	0.806
Young	32	21	0.97	0.640	0.482
Adult	32	21	0.79	0.538	0.518
Entire	32	20	0.81	0.546	0.589
Seeds					
Acer saccharum	27	.....	.....	0.27	.....
Petals					
Antirrhinum majus					
Young	32	24	1.15	1.613	1.455
Adolescent	32	24	1.13	1.374	0.970
Adult	32	24	1.00	0.668	0.487
Acanthus mollis					
Young	32	26	0.79	1.088	0.952
Adolescent	32	26	0.83	0.717	0.606
Adult	32	26	0.94	0.633	0.485
Leaves of seedlings					
"Bean" (Phaseolus?)	22	.....	.....	1.54	.....
Zea Mays					
Green leaves	37	26	0.99	1.339	0.979
Etiolated leaves	37	26	0.97	1.060	0.795
Vicia Faba					
Green leaves	37	21	0.90	1.226	0.988
Etiolated leaves	37	21	0.87	0.956	0.794
Leaves of Ligustrum japonicum					
Variegated leaves					
Green parts*	37	26	0.84	1.331	1.145
White parts	37	26	0.80	1.047	0.958
Germinating seeds					
Phaseolus vulgaris	30	.....	.....	1.276	.....
Embryo					
Hordeum vulgare	42	24	1.09	1.237	.....

* In a microchemical examination of numerous variegated leaves, ECKERSON found oxidases, peroxidases, and catalases higher in the green than in the white portions.

TABLE VII—*Continued*

Organ	Reference	Temperature (°C.)	CO_2/O_2	Mg. CO_2	Mg. O_2
				Per hour per gm. fresh (or imbibed) weight	
Pistils					
Antirrhinum majus, entire	32	20	1.00	1.186	0.864
Acanthus mollis					
Young	32	21	0.89	0.609	0.492
Adolescent	32	21	0.87	0.531	0.428
Entire	32	20	0.84	0.490	0.409
Adult	32	21	0.90	0.486	0.387
Germinating seeds					
Lupinus albus	30	.....	.....	0.990	.....
Vicia Faba	30	.....	.....	0.970	.....
Pisum sativum	30	.....	.....	0.946	.....
Cucurbita Pepo	30	.....	.....	0.878	.....
Flowers					
Syringa vulgaris	22	20	.....	0.788	.....
Leaves and leaflike structures					
Sepals of Acanthus mollis					
Adolescent	23	24	1.03	0.798	0.505
Young	33	24	1.06	0.562	0.858
Adult	33	24	0.88	0.554	0.444
Leaves					
Triticum sativum seedling					
Green	37	25	0.97	0.788	0.588
Etiolated	37	25	0.98	0.735	0.431
Hordeum vulgare seedling					
Green	37	23	0.85	0.521	0.444
Etiolated	37	23	0.83	0.423	0.371
Acanthus mollis	37	22	0.77	0.361	0.212
Antirrhinum majus	37	24	0.73	0.354	0.182
Antirrhinum majus	37	22	0.88	0.314	0.251
Malva sylvestris	37	15	0.71	0.251	0.246
Syringa vulgaris	9	22	0.94	.....	.....
Syringa vulgaris	33	22	0.94	.....	.....
Taxus baccata	9	16	0.86	.....	.....
Pinus maritima	9	20	0.85	.....	.....
Pinus sylvestris	9	24	0.80	.....	.....
Eucalyptus	9	19	0.80	.....	.....
Leaf blades					
Vicia sativa	37	18	0.75	0.590	0.574
Rumex pulcher	37	17	0.76	0.288	0.276
Geranium Robertianum	37	18	0.72	0.272	0.275
Bryonia dioica	37	17.5	0.65	0.259	0.290
Leaf petioles					
Vicia sativa	37	18	0.88	0.327	0.207
Bryonia dioica	37	17.5	0.87	0.184	0.154
Geranium Robertianum	37	18	0.91	0.086	0.068
Rumex pulcher	37	17	0.80	0.064	0.058
Tendrils					
Vicia sativa	37	18	0.90	0.504	0.408
Bryonia dioica	37	17.5	1.02	0.221	0.157
Cladodes					
Asparagus albus	37	18	0.78	0.437	0.410
Ruscus hypophyllum	37	15	0.55	0.051	0.067

TABLE VII—*Continued*

Organ	Reference	Temperature (°C.)	CO_2/O_2	Mg. CO_2 per hour per gm. fresh (or imbibed) weight	Mg. O_2 per hour per gm. fresh (or imbibed) weight
Phyllodes					
Acacia megaloxylon	37	18	0.66	0.233	0.257
Entire plant					
Pelargonium zonale	22	12–14	0.54	.....	.....
Sedum hybridum	22	25–26	0.37	.....	.....
Buds					
Aesculus					
Influence of warm bath	35	20	.....	0.188	.....
14 hours in water at 38° C.	35	20	.....	0.138	.....
14 hours in water at 20° C.	35	20	.....	0.122	.....
Stems					
Vicia sativa	37	18	0.86	0.292	0.247
Rumex pulcher	37	17	0.85	0.231	0.197
Asparagus albus	37	18	0.96	0.221	0.167
Accacia megaloxylon	37	18	0.82	0.206	0.182
Bryonia dioica	37	17.5	0.91	0.167	0.133
Geranium Robertianum	37	18	0.94	0.127	0.097
Mesembryanthemum nodiflorum	37	15.5	1.00	0.076	0.055
Ruscus hypophyllum	37	15	0.58	0.033	0.414
Bulbs					
Convallaria					
Untreated	35	19	.....	0.174	.....
After 8 hours in water at 38° C.	35	19	.....	0.133	.....
After 8 hours in water at 18° C.	35	19	.....	0.117	.....
Imbibed seeds					
Juniperus					
130 days at 5° C	38	25	0.95	0.489	0.4398
100 days at 5° C	38	25	0.68	0.2486	0.3192
90 days at 5° C	38	25	0.97	0.2354	0.2092
60 days at 5° C	38	25	0.97	0.2352	0.2152
30 days at 5° C	38	25	0.94	0.218	0.1976
5 days at 5° C	38	25	0.84	0.1311	0.1347
Chenopodium album	Table IV	20	0.928	0.175	0.141
Rumex crispus	"	20	1.16	0.151	0.095
Amaranthus retroflexus	"	20	0.857	0.113	0.096
Prunus cerasus var. Morello	"	20	0.814	0.108	0.091
P. domestica (blue gage)	"	20	0.695	0.107	0.109
P. pumila	"	20	0.878	0.093	0.076
P. armeniaca	"	20	0.628	0.089	0.102
P. domestica (Burbank plum)	"	20	0.912	0.083	0.067
P. persica	"	20	0.675	0.078	0.084
Crataegus	"	20	0.774	0.064	0.061
Zea Mays					
Embryo	42	20	0.83	0.444	.....
Endosperm	42	21	0.55	0.014	.....
Aleurone	42	.....	.....	0.009	.....
Pure endosperm	42	22	0.73	0.004	.....
Intact seed	42	18	0.77	0.003	.....
Hordeum vulgare					
Intact seed	42	26	0.83	0.203	.....
Endosperm (summer)	42	23	0.68	0.078	.....
Aleurone (summer)	42	.....	.....	0.052	.....
Endosperm (winter)	42	15	0.58	0.019	.....

TABLE VII—*Concluded*

Organ	Reference	Temperature (°C.)	CO_2/O_2	Mg. CO_2 per hour per gm. fresh (or imbibed) weight	Mg. O_2 per hour per gm. fresh (or imbibed) weight
Pure endosperm (summer)	42	23	0.36	0.019	.....
Pure endosperm (winter)	42	20	0.39	0.007	.....
Aleurone (winter)	42	.....	.....	0.001	.....
Ricinus	42	18	0.59	0.082	.....
Tubers					
Solanum					
Entire	22	.....	.....	0.006	.....
5 hours after quartering	22	.....	.....	0.480†	.....
Untreated	35	17–19	.....	0.013	.....
After 6 hours in water at 19.5° C.	.....	.....	.....	0.010	.....
After 5 hours in water at 40° C.	35	.....	.....	0.018	.....
After storage at 0° C. (starch changed to sugar)	35	19	.....	0.059	.....
After 8 hours 2 per cent aqueous ether	35	19	.....	0.068	.....
Fruits					
Russet apple	21	18	1.09	0.019	0.014
Orange	21	18	1.06	0.078	0.164
Japanese plum	21	18	1.30	0.274	0.160
Dry seeds					
Triticum vulgare					
19 per cent water	43	.....	.....	0.0054	.....
Soft red winter wheat (13 per cent water)	6	.....	.....	0.00024	.....
Secale cereale					
19 per cent water	43	.....	.....	0.0001	.....
Zea Mays					
19 per cent water	43	.....	.....	0.0001	.....
Juniperus dry seeds	38	25	0.76	0.00098	0.0011
Hordeum distichum					
33 per cent water	29	.....	.....	0.0001	.....
19–20 per cent water	29	.....	.....	0.00015	.....
15 per cent water	29	.....	.....	0.00004	.....
Algae					
Nostoc	9	19	0.40	.....	.....
Fucus	9	14–15	0.50	.....	.....
Fungi					
Aspergillus niger, Raulin's solution					
Vegetative mycelium (morning)	39	.....	1.04+	.....	.....
Vegetative mycelium (evening)	39	.....	1.05	.....	.....
Fruiting mycelium (evening)	39	.....	1.07	.....	.....
Water and 0.4 per cent salts, black conidia	39	23.5	0.66	.....	.....
Sterigmatocystis nigra					
In solutions containing					
2 gm. tannin	21	.....	1.09	.....	.....
0.9 gm. sugar	21	20	0.93	.....	.....
0.984 gm. tartaric acid	21	.....	1.78	.....	.....
0.75 gm. citric anhydride	21	33	1.40	.....	.....
0.88 gm. malic acid	21	20	1.50	.....	.....
0.80 gm. citric acid	21	20	1.48	.....	.....

† Cf. MAGNESS (31): "Removal of the epidermis facilitates the entrance of oxygen to the tissues and escape of carbon dioxide. It would be interesting to know to what extent the increased respiration following wounding is due to mechanically facilitating gaseous exchange and to what extent it is due to actual metabolic changes in the wounded tissues."

proteins was applicable as a temperature-life duration formula for wheat grains, as LEPESCHKIN himself had found it applicable for imbibed cells. Loss of viability in air-dry seeds, therefore, is probably due to "a time-temperature denaturing of certain colloids (probably proteins) of the embryo" (**16**). The retarding effect of carbon dioxide upon germination has been shown by KIDD (**28**). On the other hand, enzymes may persist and have a high degree of activity in seeds which are no longer viable, as in *Amaranthus*, or their activity may be greatly decreased without marked decrease in percentage of germination, as in Johnson and Sudan grasses (CROCKER **16**). Exhaustion of stored food cannot be considered a cause for decreased life duration in air-dry seeds, but in the case of seeds lying in the soil the situation is different. Such seeds would have a high water content, favoring chemical action, whether respiration or digestion. The actual occurrence of such reactions of course would depend upon oxygen supply, temperature, enzymes present, and the extent to which by-products (carbon dioxide, etc.) were removed. In such seeds, of which *Amaranthus* is a typical example, the life duration might easily be limited by the amount of stored substance present or by the rapidity with which it was respired or digested.

CROCKER and HARRINGTON (**16**), in studying the behavior of Johnson grass, found that storage of freshly harvested seed at 20° C. in the germinator led to an increased or secondary dormancy, a phenomenon frequently observed in seeds as a result of unfavorable germinating conditions. They suggest that such a deepened dormancy, if accompanied by a decreased respiration, may have an important bearing upon the longevity of seeds in the soil by lengthening the period necessary for the reduction of stored foods. From their own experiments on the respiration of Johnson grass they estimate the possible longevity of this seed as follows:

> If 75 per cent of the weight of the seed can be respired before death occurs, secondarily dormant Johnson grass seeds could lie in a germinator for 9.8 years at 20° C. before death would occur from exhaustion of stored foods. The period at 10° C. would likely be 2 to 3 times 9.8 years, in accord with the temperature quotient for respiration. Without such a reduction in respiratory intensity the possible longevity would be a little more than one-third as great, figured on the initial rate in the active seeds. Even if the longevity of imbibed seeds in the soil be dependent upon some contingent other than

exhaustion of stored food, this reduction in respiration is of significance. It will leave more stored material for building purposes in case germination does occur after a considerable period in the soil.

A similar calculation has been made of the rapidity with which *Amaranthus* seeds respiring at the rate observed (table IV) would exhaust their storage substance. The estimate is based on a moisture content of 47.43 per cent, and Woo's (**44**) analysis showing 47 per cent starch. On this basis the possible longevity is 160 days at the experimental temperature, 20°–25° C. This temperature is high, and respiration of stored food would certainly proceed more slowly at the lower temperature of the soil. Moreover, since observation (**7, 8, 24, 41**) shows the actual longevity of *Amaranthus* in the soil to be more than thirty years, there must be tremendous curtailment of metabolism under these conditions, with exceedingly slow use of the reserve. Even in the laboratory, dry-stored at room temperature and imbibed just before using, the seeds were viable 176 days after harvesting, and CROCKER reports that 200 days in the germinator at 20° C. does not alter their viability. If the 47 per cent fat contained in hawthorn be taken as stearin, the longevity of this seed when removed from the carpel, with 60 per cent water content, would be about 170 days at the rate of respiration observed (table IV) for the same temperature. Actually the seeds are viable for a longer time.

In all the rosaceous seeds studied variability of respiratory values was marked. Since the value of the respiratory quotient is based upon the volumes of CO_2 eliminated and of O_2 absorbed, it may serve as a convenient index of this variability. The total range of the quotient values of the six rosaceous seeds is 0.31–1.14. The extremes for individual seeds are as follows:

Hawthorn	0.47–1.14
Peach	0.56–0.96
Apricot	0.31–0.80
Cherry	0.76–1.04
Sand cherry	0.75–1.05
Blue gage plum	0.57–1.02
Burbank plum	0.72–1.04

As shown in fig. 4, with the exception of a single experiment on apricot, the quotients for all the other rosaceous seeds fall within the range of those of hawthorn. The mean for hawthorn (0.774)

lies within 0.02 of the mean of the means (table IV) for the other seeds (0.756). The rosaceous seeds, therefore, exhibit a marked similarity to one another in their respiratory behavior. If it may safely be assumed, as has been the tendency, especially among animal physiologists, that the character of respiration and particularly of the respiratory quotient depends upon the kind of substance oxidized, such a similarity would be expected, since in all these seeds the storage substance is chiefly fat.

On the other hand, in *Amaranthus*, although fluctuations in the carbon dioxide elimination and the oxygen absorption occur, and that too not always in the same, but occasionally in opposing, directions, the respiratory quotient remains relatively stable throughout a period of 176 days. The contrast in the behavior of the Rosaceae and of *Amaranthus* may be due in part to the difference in storage material, since *Amaranthus* contains little fatty substance (**44**), but much starch. This latter substance constitutes the reserve in *Chenopodium* and in *Rumex* also. It is probable, however, that other factors are responsible for the extreme variability of the rosaceous quotients.

The embryo of *Amaranthus* is not dormant. "Any time after maturity naked embryos are capable of immediate growth" (**16**). The six rosaceous seeds have dormant embryos. This dormancy, however, is of unequal intensity in different parts of the embryo. DAVIS and ROSE (**17**) and ECKERSON (**19**) have emphasized the difference in development of cotyledons and of the hypocotyl in *Crataegus*. DAVIS (**18**) finds a similar situation in the peach. It is therefore reasonable to suppose that these two parts of the embryo, cotyledons and hypocotyl, differing as they do physiologically and chemically, may differ in their metabolic activity and specifically in their oxygen absorption and carbon dioxide elimination. These differences at times may counterbalance, or at times augment, each other; or it may be that now the intensity of the hypocotyl, now that of the cotyledons, may predominate and determine the metabolism characteristic of the seed as a whole.

An analogous situation is reported by MAIGE (**32**) for stamens. In general the respiratory intensity of the adult stamen is less than that of the young organ, but this decreased intensity is differently attained in different plants. In some there is a steady decrease

from youth to age, while in others there may be an increase to a maximum followed by decline to the adult intensity, or a fall to a minimum succeeded by a return to a rate slightly lower than that at the beginning. Study of the filament and anther separately reveals the fact that their respiratory intensities are distinctly different, the anther undergoing a sort of grand period of respiratory intensity, while the intensity of the filament increases regularly from immaturity to maturity. The intensity of respiration of the stamen as a whole therefore is the resultant between these two respiratory intensities.

Great diversity of opinion exists as to the importance attaching to the respiratory quotient as an index of metabolism. In seeds like *Amaranthus* and *Chenopodium* the quotient would appear to be of significance because of its stability. The variability of the quotient in Rosaceae at first might appear to militate against its possessing any significance. When, however, this variability of the quotient is found to characterize a group possessing fundamental physiological and chemical features in common, it would seem that even here some significance might attach to the quotient. It may be of little value as indicating the material oxidized, but it may have considerable importance as indicating a situation due to the interplay of several factors. The quotient percentage curves (fig. 4) and the frequency histograms (fig. 3) show more clearly than do the tabulated data the general trend of respiration. From them can be seen that even with their variability the values for hawthorn and the other Rosaceae tend to fall into small groups about one largest assemblage. The latter, therefore, may be considered indicative of the type respiratory value for the seed.

In *Chenopodium* and *Amaranthus* the massing of the quotients is within a narrow range, and the type is more marked. Treatment of data in this way, therefore, may serve as a further check on the uniformity of conditions under which the experiments are carried out, and perhaps on the reliability of the method.

In this connection it is interesting to note that the curves in fig. 3 are of the kind found by PEARSON to be typical for botanical measurements, limited skew curves ("axis of the abcissas limited

on both sides, curve unsymmetrical"). Zoological curves, on the contrary, are unlimited skew curves ("axis of abcissas unlimited on both sides, curve unsymmetrical," 45). A possible explanation of this difference in behavior between plants and animals that suggests itself is the complication of the results of zoological experimentation due to the independent volition of the animal. Plants, placed under a given set of conditions, vary little in behavior, while uniformity of behavior in the case of different animals, or even in the case of the same animal upon successive occasions, is beyond control.

These respiratory studies in no wise answer the queries that they suggest. They are rather preliminary to further investigation. Upon one point, the difference in respiration between dormant and after-ripened but still resting *Crataegus* seeds, some data have already been obtained. That the respiration is slightly higher in the after-ripened than in the dormant seed seems well established. Further study of this point, however, is necessary.

Summary

1. The respiratory intensity, that is, the mg. CO_2 eliminated per gram imbibed seeds per hour, was determined experimentally for *Amaranthus retroflexus*, *Chenopodium album*, and *Rumex crispus*, as well as for *Crataegus* and certain drupaceous Rosaceae. Determinations of the catalase activity were also made for most of the seeds.

2. Catalase activity increases in *Crataegus* under after-ripening and germinating conditions (10° C.), up to the forty-second day. The slightly higher value for the 128th day may represent: (1) a continued increase at an extremely slow rate; (2) a limit depending on the amount of dioxogen used (5 cc.); (3) a falling off, as a result of secondary dormancy, of an activity whose maximum occurred at the completion of after-ripening (about the ninetieth day). Respiration reaches a maximum intensity much earlier (sixth to eighth day), and thereafter exhibits a slow and fluctuating decline, at least to the seventy-seventh day.

3. In *Amaranthus* both catalase activity and respiration are relatively stable. Fluctuations in catalase activity and in respiratory

intensity do not occur simultaneously, and may be in opposite directions.

4. The respiratory quotient and respiratory intensity vary markedly for different seeds, and in the Rosaceae for different lots of the same kind of seed under precisely similar experimental conditions. The respiratory quotient in *Amaranthus* and *Chenopodium* is markedly stable. Since in the Rosaceae the embryo is dormant, while in the other two seeds it is not, it may be that this difference in behavior is characteristic of seeds with dormant embryos, and the greater stability of respiration in *Amaranthus* and in *Chenopodium* represents the attainment of a more stable metabolism in these seeds.

5. Stability or variability of the quotient may be of significance as indicative of the possibility of an interplay of several factors on the metabolism. In *Crataegus*, and presumably in the other Rosaceae, the marked variability is probably the resultant between the respiration of the dormant hypocotyl and that of the mature cotyledons.

6. The arrangement of the respiratory quotients for each seed in a curve showing the percentages of the experiments with each seed giving each value, and in frequency histograms in which are plotted the actual number of experiments in which each quotient value occurred, indicates the tendency of each seed toward a typical respiration. The quotients for *Chenopodium* and *Amaranthus* are 0.928 and 0.856 respectively, while those of the Rosaceae form three groups within a range of 0.118. In the first group, between 0.648 and 0.7, fall the quotients for apricot, peach, and blue gage plum; in the third, between 0.8 and 0.876, those of cherry and sand-cherry; while that of hawthorn, 0.774, lies midway between.

Grateful acknowledgment is made to Professor WILLIAM CROCKER and to Dr. SOPHIA H. ECKERSON for the suggestion and the direction of this study, and to Dr. B. I. MILLER for her assistance in graphing the data.

UNIVERSITY OF CHICAGO

LITERATURE CITED

1. APPLEMAN, C. O., Some observations on catalase. BOT. GAZ. **52**:182–192. 1911.
2. ———, Relation of catalase and oxidase to respiration in plants. Md. Agric. Expt. Sta. Bull. 191. 1915.
3. ———, Respiration and catalase activity in sweet corn. Amer. Jour. Bot. **5**:207–209. 1918.
4. ATWOOD, W. M., A physiological study of the germination of *Avena fatua*. BOT. GAZ. **57**:386–414. 1914.
5. AUBERT, E., Recherches sur la respiration et l'assimilation des plantes grasses. Rev. Gén. Botanique **4**:203–219, 273–282, 320–331, 337–353, 373–391, 421–441, 497–502, 558–568. 1892.
6. BAILEY, C. H., and GURJAR, A.M., Respiration of stored wheat. Jour. Agric. Res. **12**:685–713. 1918.
7. BEALE, W.J., The vitality of seeds buried in the soil. Mich. Agric. Exper. Sta. Bull. 5. 1885.
8. ———, Vitality of seeds buried in the soil. Proc. 31st Ann. Meeting Soc. Prom. Sci. 1910.
9. BONNIER, G., and MANGIN, L., Recherches sur la respiration des feuilles à l'obscurité. Ann. Sci. Nat. Bot. VI. **19**:216–255. 1884.
10. BURGE, W. E., Relation between the amount of catalase in the different muscles of the body and the amount of work done by these muscles. Amer. Jour. Physiology **41**:153–161. 1916.
11. ———, A comparison of the amount of catalase in the muscles of active and inactive animals. *Ibid.* **42**:600. 1916–1917.
12. ———, Comparison of the catalase content of the breast muscle of wild pigeons and of bantam chickens. Science N.S. **46**:440. 1917.
13. ———, Catalase content of luminous and non-luminous insects compared. *Ibid.* **46**:295. 1917.
14. CROCKER, WM., Mechanics of dormancy in seeds. Amer. Jour. Bot. **3**:99–120. 1916.
15. CROCKER, WM., and DAVIS, W. E., Delayed germination in *Alisma Plantago*. BOT. GAZ. **58**:285–321. 1914.
16. CROCKER, WM., and HARRINGTON, G. T., Catalase and oxidase content of seeds in relation to their dormancy, age, vitality, and respiration. Jour. Agric. Res. **15**:137–174. 1918.
17. DAVIS, W. E., and ROSE, R. C., The effect of external conditions upon the after-ripening of the seeds of *Crataegus mollis*. BOT. GAZ. **54**:49–62. 1912.
18. DAVIS, W. E., Unpublished work on the peach.
19. ECKERSON, S. H., A physiological and chemical study of after-ripening. BOT. GAZ. **55**:286–299. 1913.
20. GARREAU, ——, De la respiration chez les plantes. Ann. Sci. Nat. Bot. III. **15**:1–36. 1851.
21. GERBER, C., Recherches sur la maturation des fruits charnus. Ann. Sci. Nat. Bot. VIII. **4**:1–277. 1896.
22. GRAFE, V., Ernährungsphysiologisches Praktikum höherer Pflanzen. 1914.

23. GROVES, J. F., Temperature and life duration of seeds. BOT. GAZ. **63**: 169–189. 1917.
24. HARRINGTON, G. T., Agricultural value of impermeable seeds. Jour. Agric. Res. **6**:761–796. 1916.
25. ———, Unpublished work on the apple.
26. HARRINGTON, G. T., and CROCKER, WM., Respiration measurements (unpublished).
27. JONES, H. A., Physiological study of maple seeds. BOT. GAZ. **69**:127–152. 1920.
28. KIDD, F., The controlling influence of carbon dioxide in the maturation, dormancy, and germination of seeds. Proc. Roy. Soc. Lond. B. **87**:408–421, 609–623. 1914; **89**:136–156. 1916.
29. KOLKWITZ, R., Über die Athmung ruhender Samen. Ber. Deutsch. Bot. Gesells. **19**:285–287. 1901.
30. LEWIN, M., Über die Atmung keimender Samen unter Druck. Ber. Deutsch. Bot. Gesells. **23**:100–104. 1905.
31. MAGNESS, J. R., Composition of gases in intercellular spaces of apples and potatoes. BOT. GAZ. **70**:308–316. 1920.
32. MAIGE, MME., Recherches sur la respiration de l'étamine et du pistil. Rev. Gén. Botanique **21**:32–38. 1909.
33. ———, Recherches sur la respiration des differents pièces florales. Ann. Sci. Nat. Bot. IX. **14**:1–62. 1911.
34. MAQUENNE, L., Sur le mecanisme de la respiration végétale. Compt. Rend. **119**:697–699. 1894.
35. MÜLLER-THURGAU, H., and SCHNEIDER-ORELLI, O., Beiträge sur Kenntnis der Lebensvorgänge in ruhenden Pflanzenteilen. I. Flora. **101**:309–372. 1910; II. *Ibid.* **104**:385–441. 1911–1912.
36. NABOKICH, A. J., Über den Einflüss der Sterilization der Samen auf die Atmung. Ber. Deutsch. Bot. Gesells. **21**:279–291. 1903.
37. NICOLAS, G., Recherches sur la respiration des organes végétatif des plantes vasculaires. Ann. Sci. Nat. Bot. IX. **10**:1–113. 1909.
38. PACK, D. A., After-ripening and germination of *Juniperus communis*. BOT. GAZ. **71**:32–60. 1920.
39. PURIEWITSCH, K., Physiologische Untersuchungen über Pflanzenathmung. Jahrb. Wiss. Bot. **35**:573–610. 1900.
40. ROSE, R. C., After-ripening and germination of seeds of *Tilia*, *Sambucus*, and *Rubus*. BOT. GAZ. **67**:281–308. 1919.
41. SHULL, G. H., The longevity of submerged seeds. Plant World **17**:329–337. 1914.
42. STOWARD, F., On endospermic respiration in certain seeds. Ann. Botany **22**:415–648. 1908.
43. WHITE, J., Ferments and the latent life of resting seeds. Proc. Rov. Soc. Lond. B. **81**:417–442. 1909.
44. WOO, M. L., Chemical constituents of *Amaranthus retroflexus*. BOT. GAZ. **68**:313–344. 1919.
45. ZIZEK, F., Statistical averages. 1913.

LEAVES OF THE HELOBIEAE[1]

AGNES ARBER

(WITH PLATE 1)

Introduction

In a paper published in 1918 (1), the phyllode theory of the monocotyledonous leaf was discussed in general terms, and in subsequent articles in this and other journals (2, 3, 4, 5) attempts have been made to trace the results of applying this theory in various special cases. In the present paper, it is proposed to study the leaves of the Helobieae, to see how far the phyllode theory will help toward interpreting them. I am indebted for material to Professor OSTENFELD of Copenhagen; to the Director of the Royal Botanic Gardens, Kew; to the Keeper of the Department of Botany, British Museum (Natural History); and to the Superintendent of the Cambridge Botanic Garden.

The Helobieae of ENGLER consist of seven families of water or marsh plants. Their common characters are difficult to define, but they are united by a macropodous embryo, and on the whole they appear to form a fairly coherent group. The seven families will be considered individually, and then the general conclusions drawn. Since I believe that the Alismaceae and their allies include the less specialized types within the cohort, these families will be discussed first, instead of following ENGLER's sequence.

Alismaceae

The literature on the protean leaf forms of the Alismaceae has been summarized elsewhere (6). The point to emphasize now is that the leaves of this family fall into three categories.

1. *Leaves with a sheathing base and a limb, more or less radial in form and phyllodic in anatomy.*—This form of leaf is rare in the family, but is found in the Sagittarias of the *S. teres* group, to which *S. isoetiformis* Smith and *S. teres* Watson belong. Fig. 1

[1] This paper represents part of the work carried out during the tenure of a Keddey Fletcher-Warr Studentship of the University of London.

represents a transverse section of the awl-like limb of one of these peculiar American Sagittarias. For comparison, by its side is a transverse section of the petiole of the normal arrowhead leaf of *S. sagittifolia* L. It will be recognized at once that both in form and structure they are essentially identical, and it will probably be generally agreed that the leaf of *S. teres* is equivalent to the arrowhead leaf of *S. sagittifolia*, minus the blade. DOMIN (9) evidently takes this view, for he uses the term "Phyllodien" in describing these leaves.

2. *Leaves with a sheathing base and a flat ribbon-like limb.*—These leaves are exceedingly common in the family, and are regarded as equivalent in morphological value to type 1, since in *S. sagittifolia* intermediate forms can be traced between thin ribbon leaves with a single row of bundles (fig. 3) and the almost radial petioles of the arrowhead type (fig. 2). For instance, among the transitional leaves between the juvenile ribbon and the mature arrowhead, a leaf was examined which was ribbon-like, but with a spathulate apex. It was found that the ribbon region was thicker than in the simple ribbon leaf, and, instead of having one series of bundles only, it had one small additional bundle above and one below the median bundle, and one below each of the main laterals, that above the median bundle being inverted. This showed an approach to the radial structure of the *S. teres* group.

3. *Leaves with a differentiated pseudo-lamina.*—I have set forth elsewhere (1) the reasons for regarding the blade of such leaves as the arrowhead as "pseudo-laminae," produced by the expansion of the distal part of the petiolar phyllode. How far the form and venation of the blades of the Alismaceae harmonize with this interpretation may now be considered. In some of the oval or cordate leaf forms there is little difficulty in seeing how the skeleton of the blade might be produced merely by the separation of the parallel petiolar veins, which at the apex return to their original approximation. This is the case, for instance, in *Alisma parnassiolium* Bassi var. *majus* (fig. 6). A further development on the same lines has taken place in *A. nymphaeifolium* Griseb. (fig. 8), in which the veins v and v', curving into the basal lobes, give off second-

ary veins, more or less parallel to themselves, and thus, without any essentially fresh departure, achieve a venation determining the auricled form of the leaf. It is probable, however, that such leaves do not form a transition to the arrowhead type, but that the latter is arrived at by a separate route.

It will be seen on examining fig. 5 (*Limnophyton obtusifolium*) and fig. 9 (*Sagittaria Greggii*) that the principal veins are the midrib (*a*) and the two veins (*b*, *b'*) passing into the cusps. In some species these cusps are very conspicuous; in *S. longiloba* they may be two or three times the length of the median segment. It is not probable that the arrowhead type of venation is derivable from that shown in fig. 8, which is, moreover, a rarity in the family. It is suggested that the veins *b* and *b'* are, as it were, a repetition of the midrib, and have originated phylogenetically by its chorisis. Their morphological relation to the midrib would thus be equivalent to the relation borne by the tendrils of *Smilax* to the petiole, according to a hypothesis put forward in a previous paper in this journal (**4**). Of course it is impossible to offer any definite proof of such a theory, but it probably makes the nature of the arrowhead leaf a shade less obscure. It seems to account for the lack of any genuinely transitional forms between the types of venation characterizing the oval and arrowhead varieties of pseudo-lamina. It is true that the intermediate forms have very short cusps, but their venation is distinctly of the arrowhead type.

Butomaceae

The Butomaceae are so closely related to the Alismaceae that they are sometimes regarded merely as a tribe of the latter family. Among the Butomaceae we find examples of the three types of leaf enumerated under the Alismaceae. *Butomus umbellatus* L. has a leaf with a sheathing base, and an upper region which is triangular in section and phyllodic in anatomy (**17**). On the other hand, *Hydrocleis Commersonii* Rich. and *H. parviflora* Seub. have both ribbon leaves and leaves with a petiole and pseudolamina (**10, 18, 20**). The published figures of these ribbon leaves suggest that they are equivalent to the ribbon leaves of *Sagittaria*, but I have not had the opportunity of examining their anatomy.

Juncaginaceae

Of the five genera of Juncaginaceae, none possesses leaves with pseudo-laminae. Certain species of *Triglochin* have ribbon-like leaves, for example, *T. montevidense* Spreng., figured by SEUBERT (**18,** pl. XII), and *T. procerum* R.Br. It is hoped to deal with the leaf anatomy of this genus in a later paper. Except in the case of these few ribbon-leaved species, all the five genera have leaves with a sheathing base and a radial or ensiform limb, with a typically phyllodic anatomy. In *Triglochin*, *Lilaea*, and *Scheuchzeria*, a ligule generally marks the boundary between sheath and limb (**9**). Fig. 7 shows the transverse section of the limb of the leaf of *Scheuchzeria palustris* L. Its curious asymmetry has been figured and commented on by RAUNKIAER (**15**). The leaf of the monotypic *Maundia*, judging from BUCHENAU'S figure of the transverse section (**8,** fig. 7, p. xvi), is phyllodic, and similar to that of *Triglochin maritimum* (**1**). I have cut the leaf of the monotypic *Lilaea subulata* Humb. et Bonpl., and, although the herbarium material available was not very favorable for anatomical work, it was obvious that here also the structure is phyllodic. The leaf, which is described as awl-shaped and cylindrical in the fresh condition, is supplied by a series of small peripheral bundles in addition to three main strands. HIERONYMUS (**11**), in a Spanish monograph of *Lilaea* published forty years ago, definitely states that the leaves of this plant consist only of sheath and petiole, the lamina being unrepresented.

It was interesting to find, on examining the fifth genus (the monotypic *Tetroncium magellanicum* Willd.) that the leaf is unusual among the Helobieae in being of the ensiform type, and in having a bundle system identical with that of the isobilateral equitant leaves which are so familiar, for instance, in *Iris*. In fig. 4, *A* shows the structure of the sheath region, *B* the transition to the limb, and *C* the limb itself, which has a close anatomical resemblance to that of *Tofieldia calyculata* Wahl., one of the equitant members of the Liliaceae (**1**). Fibrous sheaths are associated with the bundles.

Potamogetonaceae

In this family there are three types of leaf, corresponding to those met with in the Alismaceae and Butomaceae. The rarest

type is the leaf with a sheathing base and more or less radial limb with phyllodic anatomy. This leaf form is found in *Cymodocea isoetifolia* Aschers. (fig. 11), described by SAUVAGEAU (**16**) and OSTENFELD (**14**). A ring of bundles surrounds the median strand. The same genus also includes leaves in which the limb is flat and furnished with only one series of bundles (as *C. nodosa* Aschers., fig. 12), while *C. manatorum* Aschers. (fig. 10), with its more or less terete leaf, traversed by three strands only, forms an intermediate type. In each species there is a ligule, clearly delimiting the sheath from the petiolar region.

In *Potamogeton* the leaves of some species, like the air leaves of many Alismaceae, possess pseudo-laminae. In *P. natans* L. there are, in addition, bladeless, terete, phyllodic leaves, corresponding exactly in structure and anatomy to the petioles of the fully developed leaves (**16**), and which may be regarded as equivalent to the leaves of *Cymodocea isoetifolia*. *P. natans* also has leaves showing a further degree of reduction, but instead of being ribbon-like, as in the Alismaceae, they consist almost entirely of the highly developed axillary stipules or ligules.

Naiadaceae

The leaves of the Naiadaceae are much reduced, but they have a sheath and a thin flat limb, and thus correspond to the ribbon leaves of *Sagittaria*.

Aponogetonaceae

Only the one genus, *Aponogeton*, is included in the Aponogetonaceae. Most of the species have leaves with a differentiated sheath, petiole, and pseudo-lamina, but *A. vallisnerioides* Bak. has ligulate ribbon leaves, described (**7**) as resembling those of *Vallisneria*, while in *A. spathaceum* E. Mey. var. *junceum* Hook. f. (**12**) semiterete leaves with a sheathing base are found. A piece of a leaf of this variety which was examined did not include the distal part of the leaf, but showed the structure of the transition region between sheath and limb. In addition to the three main bundles, which HOOKER indicates in a slightly magnified transverse section which he figures, there are a number of small peripheral bundles. The structure is thus closely equivalent to that of the petiole of such a species as *Aponogeton distachyum* Thunb.

Hydrocharitaceae

In the Hydrocharitaceae all three types of leaf which have been considered are found. In *Stratiotes* and *Enhalus* there is no blade, and the occurrence of inverted bundles (**13, 19**) gives a phyllodic aspect to the anatomy. These leaves may be regarded as equivalent to that of *Butomus*, but in *Stratiotes* there is no sheath, although this region is developed in *Enhalus*. *Hydrocharis* has a leaf with a stipulate sheath, a petiole, and a pseudo-lamina, while the leaves of *Vallisneria* and *Thalassia* are similar to the ribbon leaves of *Sagittaria*. *Vallisneria* has a sheath which may easily be overlooked, while in *Elodea* this region is entirely lacking (**9**).

Conclusions

A comparison of the leaf structure in the various families belonging to the Helobieae shows the repeated occurrence of that leaf type in which there is a sheathing base succeeded by a bladeless limb, in appearance and structure recalling a petiole. Such leaves, instances of which are met with in six of the seven families, are regarded as *typical petiolar phyllodes*. This simple phyllodic form of leaf is most characteristically developed in the Juncaginaceae, where it occurs in all five genera. The leaves in this family are generally more or less radial, except in *Tetroncium*, where they are ensiform and *Iris*-like. In the other families leaves of approximately radial structure occur more or less sporadically, or as rarities, except in the Naiadaceae, where they are entirely lacking. The extreme reduction of the one genus *Naias*, which constitutes the family, however, makes the absence of such leaves by no means surprising.

In each of the seven families examples of a leaf with a sheathing base and flat ribbon-like limb are found. This leaf is regarded as equivalent to the more obviously phyllodic type of leaf just discussed. Two lines of evidence point to this conclusion: (1) within the single species *Sagittaria sagittifolia* L. transitions, both in external form and internal structure, can be found between typical ribbon leaves and petioles; and (2) within *Cymodocea* not only typical ribbon leaves (as *C. nodosa*, fig. 12) and typical petiolar leaves (as *C. isoetifolia*, fig. 11) are found, but also in *C. manatorum* (fig. 10) there is an intermediate link between these two types.

The third and last leaf type, that in which there is a differentiated blade, occurs in five of the seven families, the exceptions being the Juncaginaceae and Naiadaceae. It is not necessary here to discuss the evidence, based partly on a study of the succession of leaf forms in the ontogeny, and partly anatomical, which has led to the conclusion that these blades are "pseudo-laminae," originating by the expansion of the apex of the petiolar phyllode, for this question has been considered elsewhere (**1**, **6**). The present paper adds a study of the significance of the blade venation of the Alismaceae.

The final impression left by this survey of the leaves of the Helobieae is that there has been a remarkable parallelism of development within the different families. The three leaf types enumerated recur throughout the cohort in forms which, although modified in various ways, are identical in essentials.

BALFOUR LABORATORY
CAMBRIDGE, ENGLAND

LITERATURE CITED

1. ARBER, AGNES, The phyllode theory of the monocotyledonous leaf, with special reference to anatomical evidence. Ann. Botany **32**: 465–501. 1918.
2. ———, The vegetative morphology of *Pistia* and the Lemnaceae. Proc. Roy. Soc. B. **91**:96–103. 1919.
3. ———, Leaf base phyllodes among the Liliaceae. BOT. GAZ. **69**:337–340. 1920.
4. ———, Tendrils of *Smilax*. BOT. GAZ. **69**:438–442. *pl. 22*. 1920.
5. ———, On the leaf structure of certain Liliaceae, considered in relation to the phyllode theory. Ann. Botany **34**:447–465. 1920.
6. ———, Water plants: a study of aquatic Angiosperms. Cambridge University Press. 1920.
7. BAKER, J. G., and GRANT, J. A., The botany of the Speke and Grant expedition. Trans. Linn. Soc. **29**:1–190. 1875.
8. BUCHENAU, F., Scheuchzeriaceae in Das Pflanzenreich IV. **14**:1–20. 1903.
9. DOMIN, K., Morphologische und phylogenetische Studien über die Stipularbildungen. Ann. Jard. Bot. Buit. **24**:117–326. *pls. 11*. 1911.
10. ERNST, A., Über Stufengang und Entwickelung der Blätter von *Hydrocleis nymphoides* Buchenau (*Limnocharis Humboldtii* C. L. Richard). Bot. Zeit. **30**:518–520. 1872.
11. HIERONYMUS, G., Monografía de *Lilaea subulata*. Act. Acad. Nac. Ciencias en Córdoba. **4**:1–52. *pls. 5*. 1882.
12. HOOKER, J. D., *Aponogeton spathaceum* E. Mey. var. *junceum*. Curtis's Bot. Mag. **34**: *pl. 6399*. 1878.

13. MAGNUS, P., Über die Anatomie der Meeresphanerogamen. Sitz.-Ber. Gesells. Nat. Freunde Berlin 1870. 85–90.

14. OSTENFELD, C. H., Contributions to West Australian botany. Part I. Introduction. The sea-grasses of West Australia. Dansk Bot. Arkiv **2**:1–44. 1916.

15. RAUNKIAER, C., De Danske Blomsterplanters Naturhistorie. I. Enkimbladede, 1. Helobieae. 1–138. Copenhagen. 1896.

16. SAUVAGEAU, C., Sur les feuilles de quelques monocotylédones aquatiques. Ann. Sci. Nat. VII. Bot. **13**:103–296. 1891.

17. ———, Sur la feuille des Butomées. Ann. Sci. Nat. VII. Bot. **17**:295–326. 1893.

18. SEUBERT, M., in MARTIUS, Flora Brasiliensis **3**: part 1. 1842–71.

19. SOLEREDER, H., Systematisch-anatomische Untersuchung des Blattes der Hydrocharitaceen. Beih. Bot. Centralbl. **30**:24–104. 1913.

20. WÄCHTER, W., Beiträge zur Kenntniss einiger Wasserpflanzen. Flora **83**:367–397. 1897.

EXPLANATION OF PLATE I

The plate shows the xylem in black, the phloem in white, the fibers (*f*) dotted, and the outlines of lacunae in dotted lines.

FIG. 1.—*Sagittaria* of *S. teres* group: transverse section of limb of leaf *f*, interrupted fibrous sheath of bundle (slight asymmetry of section probably due to incomplete recovery of herbarium material used; Georgia Plants. Roland Harper. 1473. Ex Herb. Brit. Mus.); ×23.

FIG. 2.—*Sagittaria sagittifolia* L.: transverse section of petiole close to blade, fibrous bundle sheath (less highly developed than in species shown in fig. 1) not indicated; ×14.

FIG. 3.—*Sagittaria sagittifolia* L.: transverse section of small ribbon leaf, ×23.

FIG. 4.—*Tetroncium magellanicum* Willd.: transverse sections of leaf; *A*, sheath, *B*, transition to limb; *C*, limb; ×23.

FIG. 5.—*Limnophyton obtusifolium* Miq.: blade of leaf; *a*, midrib; *b*, *b'* cusp veins (serration of margin probably an effect of drying); ×0.5.

FIG. 6.—*Alisma parnassifolium* Bassi var. *majus*, blade of leaf; ×0.5.

FIG. 7.—*Scheuchzeria palustris* L.: transverse section of limb of leaf; *f*, fibrous strand occupying one margin (on account of small scale, fibrous sheaths of bundles not separately indicated); ×23.

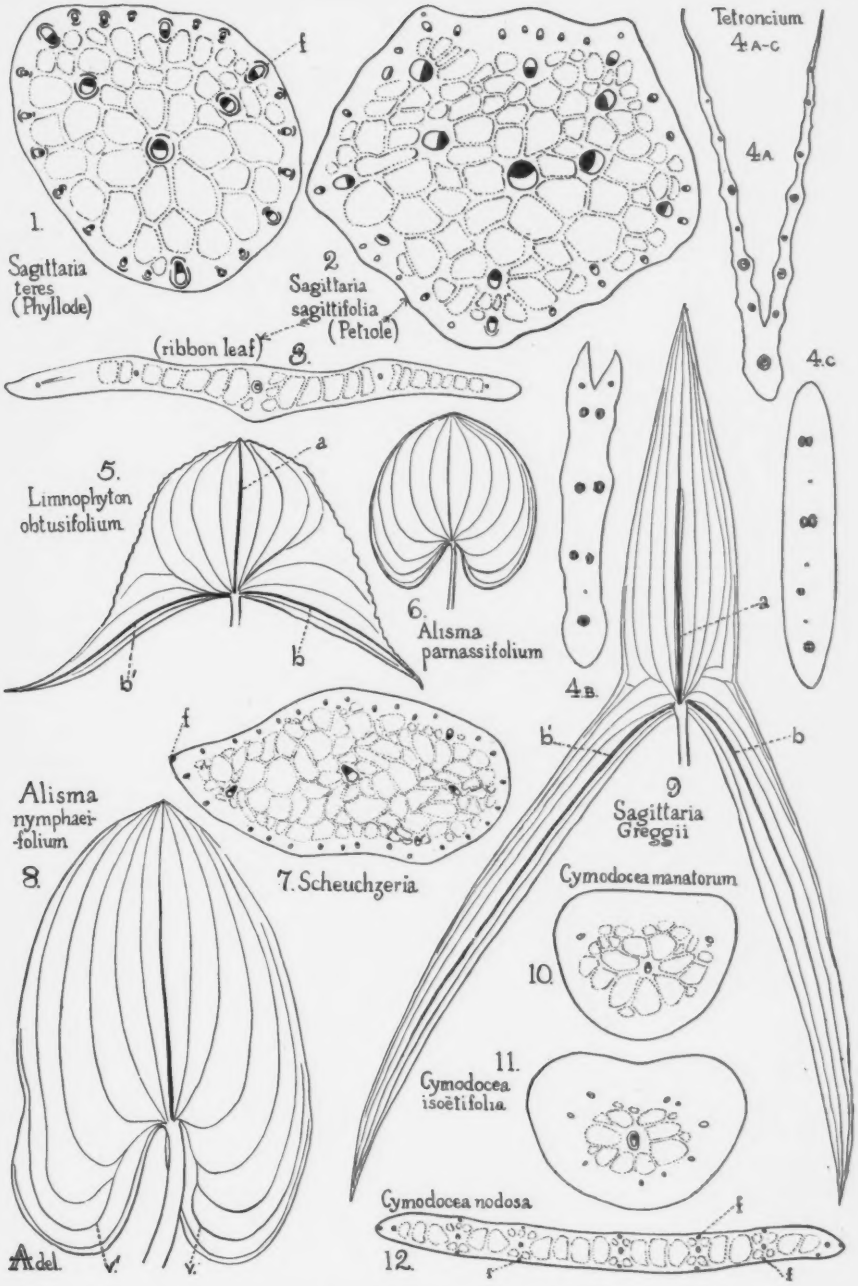
FIG. 8.—*Alisma nymphaeifolium* Griseb.: blade of leaf; *v*, *v'*, principal veins of auricles; ×0.5.

FIG. 9.—*Sagittaria Greggii* Smith.: blade of leaf; *a*, midrib; *b*, *b'*, cusp veins; ×0.5.

FIG. 10.—*Cymodocea manatorum* Aschers.: transverse section of limb of leaf; ×23.

FIG. 11.—*Cymodocea isoetifolia* Aschers.: transverse section of limb of leaf; xylem indistinguishable, in smaller bundles surrounding median bundle; ×23.

FIG. 12.—*Cymodocea nodosa* Aschers.: transverse section of limb of leaf; ×23.



ARBER on HELOBIEAE

NOTES ON NEW OR RARE SPECIES OF RUSTS

W. H. LONG

This paper describes four new species of rusts, namely, *Gymnosporangium cupressi* on *Cupressus arizonica*, *Ravenelia subtortuosae* on *Acacia subtortuosa*, *Ravenelia gooddingii* on *Acacia suffrutescens*, and *Ravenelia cassiae-covesii* on *Cassia covesii*, and gives new data as to hôsts and distribution of two other species of *Ravenelia*.

Gymnosporangium cupressi Long and Goodding, sp. nov.

I. Aecia unknown.

III. Telia caulicolous, from a perennial mycelium, appearing on twigs, branches, and trunks, causing fusiform to subglobose swellings 1–90 cm. long by 0.5–30 cm. thick, usually breaking forth irregularly and often transversely on the smaller branches and twigs, in irregular rows in deep longitudinal fissures of the bark on the larger branches and trunks. When mature, telia are more or less wedge-shaped, often irregular and somewhat crenate at top, before gelatinization 2–10 mm. broad by 4–6 mm. tall, dark chestnut brown, becoming cinnamon brown after expansion; teliospores 2-celled, spores with colored walls, oval to ellipsoid, 22–27×43–50 μ, average for ten spores 24.2×49 μ, slightly or not at all constricted at the septum, the two cells subequal, pedicel cylindrical, pores two in each cell near septum, walls 2–3 μ thick; teliospores with thin, colorless walls, oblong to narrowly ellipsoid, not constricted at septum, 16–20×40–60 μ, average for ten spores 18.6×53 μ, the two cells subequal, spores rounded at both ends, pores two in each cell at the septum, walls 1–1.5 μ thick.

On Juniperaceae. Type collected on *Cupressus arizonica*, at Snebly Hill, 3.5 miles from Sedona, Arizona, May 26, 1920, by *Leslie N. Goodding* (no. 6906 Long); also collected on same host and in same locality in 1919 by *Goodding* (no. 6903 Long). Collected on same host on road between Cottonwood and Sedona, 6 miles from Sedona, May 26, 1920, by *Goodding* (no. 6904 Long). This fine species of *Gymnosporangium* is probably generally distributed on this host in the draws and canyons around Sedona at an elevation of about 4000 ft.

Ravenelia subtortuosae, sp. nov.

0. Pycnia; none found in material at hand.

I. Aecia caulicolous, thickly scattered over hypertrophied areas which form open witches' brooms 1–2 cm. across. Aecia 0.2–0.3 mm. in diameter by 0.8–1.2 mm. high, cylindrical, subepidermal, peridium erect, margin erose and gradually weathering away to base, cells irregularly oblong to polygonal in face view, not overlapping, outer walls 5–6 μ thick, verrucose, inner ones 2–3 μ thick, verrucose, both walls appearing as if reticulate in certain views, side walls 2–3 μ thick, transversely striate; aeciospores irregularly oval to subglobose, angular, 13–18×18–23 μ, average for ten spores 17×19.6 μ, walls cinnamon brown, 2–3 μ thick, minutely verrucose.

II. Uredinia amphigenous, very small, less than 0.3 mm. across, rather firm, punctiform, subepidermal, ruptured epidermis inconspicuous; urediniospores obovate, subpyriform to oval, 15–22×22–30 μ, average for twenty spores 17.3×25.7 μ, chestnut brown, concolorous, or sometimes slightly darker at apex, walls 1.5–2 μ thick, uniform, verrucose, germ pores six, equatorial; paraphyses very abundant, often constituting one-third to one-half of sorus, hyphoid, incurved, chocolate brown, dense, encircling the sorus, 10–13×40–50 μ, average for ten 10.3×43.6 μ, an occasional paraphysis clavate, nearly colorless and with a solid stipe.

III. Telia amphigenous, oval, 0.5–1 mm. across, chestnut brown, subepidermal, ruptured epidermis inconspicuous, early naked; paraphyses none; teliospore heads light brown, hemispherical to ovoid, very irregular in shape and size, 33–100 μ, average for forty heads 52.5 μ, 3–6 spores across, marginal spores 3–16, inner spores 0–12, spores in head 3–32, usual number 14–25, smooth, outer spores 1-celled, inner ones 2-celled; cysts small, hyaline, subappressed; ovoid, as many as the marginal spores, cohering at sides to each other but not to stipe, swelling and bursting in water; pedicel hyaline, compound, deciduous, short, 32–55 μ long.

On Mimosaceae. Type for aecia collected on *Acacia subtortuosa* at Corpus Christi, Texas, May 25, 1918, by *W. H. Long* (no. 6506). Type for

uredinia and telia collected on same host and in same locality June 25, 1920, by *Long* (no. 6891); also collected at Darling, Texas, on same host June 19, 1920, by *Long* (no. 6892).

The aecial stage of this *Ravenelia* is very conspicuous, while the other two stages are just the reverse. In fact, to find the uredinia and telia one must look on the leaves immediately adjacent to the aecial stage. At Darling, a flag station about 12 miles from Spofford Junction, the old witches' brooms of this *Ravenelia* were very abundant for about 1 mile along the railroad track. Often some bushes would have from fifteen to twenty-five "brooms." An occasional urediniospore was found intermixed with the telia in the Darling material.

In the 1918 collection aecia and telia were found. The telia were very rare, only a few sori to each bush. In the 1920 material collected in the same catclaw-mesquit field, an abundance of both uredinia and telia were found associated directly with the old witches' brooms. The uredinia were found on bushes growing in low damp spots with branches dense and close to the ground. On account of the abundance of the uredinia and telia in the 1920 material this collection was made the type of these two stages.

The uredinial stage of *Ravenelia subtortuosae* bears a close resemblance in all of its characters to the same stage of *R. australis* (as it occurs in Texas), even to the paraphyses, but differs materially in its telia from this species. *R. subtortuosae* is also related to *R. MacOwaniana*, found in south and central Africa on *Acacia horrida*, but differs from this species in many important characters.

This is the only *Ravenelia* known to the writer reported from the Americas that has the three stages, aecia, uredinia, and telia.

Ravenelia gooddingii, sp. nov.

c. Pycnia unknown.

II. Uredinia small, sparse (in material examined), hypophyllous, scattered, subcuticular, early naked, cinnamon brown; paraphyses very abundant, intermixed with the spores or in separate sori, subcylindrical to narrowly clavate, a few obovate, clavate type with thick walls and nearly solid heads, upper one-half to two-thirds of head fulvous, balance hyaline or nearly so, stipe solid, hyaline, 10–14 by 40–50 μ, obovate type thin-walled, subhyaline, with apex sometimes slightly thickened and fulvous, 15–18 × 30–55 μ; urediniospores broadly oval to globoid, 12–16 × 16–19 μ, walls pale fulvous, thin, 1–1.5 μ, verruculose, pores 6–8, scattered.

III. Telia amphigenous, but mainly hypophyllous, often seated on pallid spots, usually found on basal half of the leaves, very irregular, 0.5–1.5 mm. × 2–4 mm. long, often confluent over one-half to two-thirds of the leaf, subcuticular, early naked, shining,

chocolate brown, ruptured cuticle inconspicuous; paraphyses none, teliospore heads light chestnut brown, 5–6 cells across, 60–80 μ, average for twenty heads 70.3 μ, 8–16 marginal cells, 8–18 inner ones, heads more or less flattened, smooth; cysts hyaline, in two rows beneath the entire head, appressed, not cohering, oval to obovate, easily swelling and bursting in water; pedicel short, hyaline, deciduous.

On Mimosaceae. Type collected on *Acacia suffrutescens* in Baboquivari Mountains, Arizona, October 24, 1919, by *Leslie N. Goodding* (no. 6983 Long).

Ravenelia cassiae-covesii Long and Goodding, sp. nov.

0. Pycnia unknown.

II. Uredinia amphigenous, scattered, round or irregular, 1–2 mm. across, subcuticular, early naked, cinnamon brown, ruptured cuticle inconspicuous; paraphyses very few, intermixed with the spores, clavate-capitate to capitate, hyaline, 11–13×37–66 μ, average for ten paraphyses 12.5×48 μ, stipe solid, hyaline, about 5 μ thick, walls of heads thin, 1–1.5 μ thick, smooth; urediniospores broadly ellipsoid, obovate to subglobose, 15–20×17–23 μ, average for forty spores 17.2×20.1 μ, walls cinnamon brown, 2–2.5 μ thick, verrucose-echinulate, germ pores eight, in two irregular zones of four pores each, equidistant from the equator, or scattered in the subglobose type.

III. Telia amphigenous and caulicolous, scattered, round, 0.5–1 mm. across, subcuticular, early naked, chocolate brown, ruptured cuticle inconspicuous; paraphyses few, similar to those found in the uredinia; teliospore heads chocolate brown, 5–7 cells across, 50–84 μ, average for forty heads 65.3 μ, 6–14 marginal cells, 6–20 inner ones, heads smooth or with half to two-thirds of the cells bearing a single, wartlike, semihyaline papilla, 1–4 μ long, to each cell; cysts numerous, hyaline, globose, subappressed, in two or three rows, beneath entire head, slowly swelling and bursting in water; pedicel short, hyaline, deciduous.

On Caesalpiniaceae. Type collected on *Cassia covesii* near Tucson, Arizona, by *H. W. Thurston* and *Leslie N. Goodding*, February 26, 1920 (no. 5537 Long); also collected on same host in Sabino Canyon, near Tucson, March 9, 1920, and January 4, 1921, by *Leslie N. Goodding* (nos. 6918 and 6972 Long).

This species is intermediate between *Ravenelia mesillana* and *R. papillifera*. Some of the mounts from the material collected near Tucson (no. 5537) have nearly all of the teliospore heads smooth, while other slides from the same locality, as well as the material collected in Sabino Canyon (no. 6918 Long) in the foothills of the Santa Catalina Mountains, have a large number of the heads papillate.

Ravenelia siliquae Long

This rust was collected June 1920, at San Antonio, Texas, on the leaves, twigs, branches, and pods of *Acacia farnesiana*. In many cases young pods were found with the uredinia just sporulating, while the leaves and twigs of the same tree showed old uredinia. This proves the writer's contention in a previous article[1] that the twig and leaf rust on this host was *R. siliquae*, which up to that time had only been collected on the pods.

Ravenelia fragrans Long

A *Ravenelia* collected on the leaves and pods of *Mimosa biuncifera* in Arizona, by *Leslie N. Goodding*, was sent to the writer for identification. A careful comparison of this material with the type of *R. fragrans* shows no essential characters sufficient to warrant making it a new species. The paraphyses in the Arizona rust are slightly more clavate than those found in the typical *R. fragrans*, while many of the teliospore heads are nearly smooth. Each of the papillate cells bears 1–4 hyaline papillae, 1–3 μ long. The stipe is usually short, hyaline, and deciduous, but occasionally one is found which measures up to 100 μ. Many telial heads of the typical *R. fragrans* show cells with few and very short papillae similar to the Arizona material.

This rust has been collected in two localities in Arizona, the Baboquivari Mountains, October 24, 1919 (nos. 6534 and 6535 Long), and Rosemond, December 17, 1920 (no. 6969 Long). The latter collection has a large percentage of the teliospore heads smooth or with only an occasional head showing any papillate cells, while the 1919 material has heads fairly typical of *R. fragrans* as it occurs on *Mimosa fragrans*, yet the two collections are unquestionably the same species.

[1] Notes on new or rare species of *Ravenelia*. Bot. Gaz. 64:57–69. 1917.

On a recent trip (June 1920) through Texas many areas were revisited which in May and November of 1916 showed an abundance of *Ravenelia* infection of many different species, yet only occasionally was any *Ravenelia* found, although a careful search was made on hundreds of plants which in 1916 were literally covered with *Ravenelia* sori. The species of *Ravenelia* so abundant in 1916 were as follows: *R. siderocarpi*, *R. papillifera*, *R. roemerianae*, *R. mesillana*, *R. gracilis*, *R. leucaenae*, *R. siliquae*, and *Neoravenelia holwayi;* of these only *R. siliquae* was at all common in 1920. This would indicate that certain years are very favorable for the propagation and dissemination of species of *Ravenelia*. This fact, of course, is well known in connection with various species of grain rusts.

OFFICE OF INVESTIGATIONS FOREST PATHOLOGY
BUREAU OF PLANT INDUSTRY
ALBUQUERQUE, N.M.

BRIEFER ARTICLES

HELMUT BRUCHMANN

(WITH PORTRAIT)

The name of BRUCHMANN has become so familiar through his indefatigable researches upon the prothallia of temperate species of *Lycopodium*, that some account of his life should appear in this journal, which has so often paid the last tribute of respect to great botanists.

HELMUT BRUCHMANN was born in Pomerania, Prussia, on November 13, 1847, and death came suddenly at Gotha on Christmas 1920. After the usual studies in local schools, he went to Jena, where STRASBURGER was beginning his great career as a teacher, investigator, and maker of investigators. Although I cannot find any authoritative data, it is my recollection that STRASBURGER himself told me that BRUCHMANN was the first man to take the Ph.D. degree under his direction, and that the thesis dealt with *Lycopodium*. STRASBURGER held him in the highest esteem and made him his assistant. Like STRASBURGER, he was a master of technique, making splendid sections before the days of paraffin and microtomes. In 1878, at the age of 29, he went to Tharand to deliver a course of lectures on forestry; and a year later was called to Gotha as teacher of mathematics and physics, and afterward biology, in the high school. STRASBURGER offered him an "ausserordentlich" professorship at Jena, but the stipend attached to that position at that time was so small that he felt compelled to remain at Gotha, with the comparatively comfortable salary of 2400 marks. Since BRUCHMANN married Fräulein EMMA JUSATZ in 1880, one might

surmise what prompted the decision. She shared, in an unusual degree, the cares and joys of his school life, and was intimately acquainted with his investigations and discoveries. For thirty years he taught mathematics and physics in the high school at Gotha, spending vacations and leisure hours in his patient and thorough investigations of *Lycopodium*. He was a successful teacher, reaching the highest rank in the school and often assuming the duties of Director. His thorough knowledge of his subject, together with a kindly, sympathetic disposition, won for him the respect and affection of his students. In 1905 his health became impaired, and he went to the Riviera to recuperate; but after several months, not feeling strong enough to resume the heavy burden of teaching, he retired upon a pension. In 1907, he visited Sicily, Tunis, and Algiers. In his later years, failing eyesight made the search for subterranean prothallia very difficult.

BRUCHMANN'S great contribution to science was his prolonged and successful investigation of the prothallia of the European species of *Lycopodium*. When he began his studies, nothing was known of the prothallia of temperate species except fragmentary accounts of the aerial prothallia of *L. inundatum* and the subterranean prothallia of *L. annotinum*. BRUCHMANN succeeded in finding practically complete series in the development of the prothallia of *L. complanatum*, *L. annotinum*, *L. clavatum*, and *L. Selago;* and his excellent histological technique and his skill as an artist, together with a clear literary style, enabled him to make an effective presentation of his researches and conclusions. Altogether there are 17 papers, but the most important are "Über die Prothallien und die Keimpflanzen mehrerer Europäischer Lycopodien," an extensive account with 199 pages and 8 plates, which appeared in 1898; and "Die Keimung der Sporen und die Entwickelung der Prothallien von *Lycopodium clavatum*, *L. annotinum*, und *L. Selago*," which appeared in *Flora* in 1910.

Although botanists, from the time of HOFMEISTER, have tried to germinate the spores of *Lycopodium*, no one but BRUCHMANN ever succeeded with the difficult species which have subterranean prothallia. Some may have failed by throwing away their cultures too early, for the spores of *L. Selago* germinated in 3–5 years; the development of archegonia and antheridia was complete only after 6–8 years; while *L. clavatum* and *L. annotinum* were even slower, germinating after 6–7 years, and requiring 12–15 years to produce an egg ready for fertilization. A long series of cultures in the laboratory, with checks in the field, finally enabled him to give a complete account of the germination of the spore,

development of the gametophyte, fertilization, and embryogeny. BRUCHMANN'S success stimulated others, and while no one else found any prothallia of European species, SPESSARD found American species, HOLLOWAY found prothallia of New Zealand species, while both HOLLOWAY and LAWSON discovered the prothallia of *Tmesipteris* and *Psilotum*.

BRUCHMANN naturally became interested in other subterranean prothallia, and succeeded in finding prothallia of *Ophioglossum vulgatum* and *Botrychium Lunaria*, both of which he described in his usual thorough manner. *Selaginella*, since it is a lycopod, was investigated, although its prothallia are not subterranean. He also made a study of the behavior of the sperms of lycopods with special reference to chemotaxis.

The paper of 1898 brought widespread recognition, for in 1899 he received the Plato Medal of the Academy of Science of Munich, and in the following year the Demazières Prize of the Paris Academy of Sciences, which carries with it a monetary consideration of 1500 francs. Still later he was made an honorary member of the Naturforschende Gesellschaft of Berne. In a letter received by the writer in 1911, however, BRUCHMANN states that, while the prizes are gratifying, his greatest satisfaction is in the recognition his work is receiving in textbooks which bring his results before students in the schools. His experience as a teacher prompted him to prepare splendid sets of prothallia for laboratory demonstration, and these are now used in most German universities and in many universities of other countries.

BRUCHMANN'S life and patient, persistent work prove that one who has the interest and will to do research work can achieve a high rank in science without the stimulus of a great university.—CHARLES J. CHAMBERLAIN, *University of Chicago*.

CURRENT LITERATURE

BOOK REVIEWS

Actinomycetes

The last decade has witnessed the publication of a considerable number of lengthy papers dealing with one or more species of the genus *Actinomyces*. None, however, has equaled, either in volume or in scope, LIESKE'S[1] recent book, in which are incorporated the results of seven years of research, besides considerable information obtained from the very extensive bibliography, of which nearly 400 titles, representing only a part of the total, are cited. The largest section of the volume is devoted to a treatment of the physiological properties of the Actinomycetes, including their reactions to nutrient and tonic compounds, their production of odors and pigments, their enzymatic activities, as well as a discussion of variations of different strains of *Actinomyces* arising in response to changed conditions, or quite spontaneously under uniform conditions. The spontaneous variations with respect to chromogenesis, sporulation, oxygen requirements, thermal relations, and production of odors, the author regards as being in the nature of mutations. The two final sections of the book deal with the relation of the group of organisms to animal and human diseases, and to the diseases of higher plants. In connection with the latter, the galls of alder roots are discussed, and a certain amount of evidence, unfortunately not altogether conclusive, is adduced to show that the causative organism is a species of *Actinomyces*.

In the Preface, the author expresses the justifiable hope that the book may have been made to embrace both the botanical and the medical provinces of bacteriology. He sees in the methods of medical bacteriology a more highly developed technique, from the use of which botanical investigations might profit. Accordingly it is not surprising that the research reported in the book, not excluding the section on morphology, is the product of the established type of medical bacteriological technique, although the latter thus far can hardly be credited with having revealed much concerning the structure of any group of microorganisms. The material to be studied appears largely to have been crushed or smeared on the slide, fixed by heating, and stained by Gram's method. The author concludes that septa are absent from the aerial sporulating filaments, which in view of the fact that the stains used fail to show the walls of fungi, even when these are clearly visible in unstained preparations, need occasion no astonishment. It is to be regretted that some stain known

[1] LIESKE, RUDOLF, Morphologie und Biologie der Strahlenpilze (Actinomyceten). 8 vo. pp. ix+292. *pls.* 4 (colored). *figs.* 112. Leipzig: Gebrüder Borntraeger. 1921.

to affect wall material, as, for example, Delafield's haemotoxylin applied for several hours, was not tried. The process of sporulation is held to be similar to the division of bacteria, and is generally referred to as a breaking up ("Zerfall") of the filaments, both aerial and submerged. It appears difficult to understand why the irregular degenerative structures developed in submerged material, shown in fig. 49, should be designated as spores at all. In fig. 44, showing the development of aerial spores, sporulation is represented as involving the filament below the point of insertion of a branch, a condition which perhaps it might be not at all easy to find realized in any preparation. A new type of spore is also described, the "Vierhyphenspore." The development of the latter is initiated by the proliferation of two short branches at right angles near the tip of a filament. The four elements about the intercalary portion then assume symmetrical positions with reference to it, and yield their contents to the intercalary portion, the latter thus becoming the spore. Although nuclear fusions were not observed, the author believes it probable that some sort of sexuality may be present, the figures observed appearing to show some similarity to the so-called zygospores of certain microorganisms. In spite of the remarks of the author, the figures illustrating these structures do not impress the reader as anything especially distinctive, and he is left to wonder why the author saw here a character recalling the fungi, when he failed to find fungus characteristics in the incomparably more distinctive sporogenous apparatus.

In general the author seems inclined to minimize the significance of such fungus-like characteristics as are revealed even on smear preparations stained according to GRAM. He recognizes in the Actinomycetes a group of organisms occupying an independent position between the fungi and the bacteria, but more closely related to bacteria, particularly to those of the acid-fast type. As to a taxonomy of species, he offers little in the way of encouragement to followers of precedent. The concept of species he holds to be utterly impossible to apply here, all strains showing an exceptional degree of variability under different conditions, and the presence of intergrading strains bridging over whatever differences may be observed between extremes. Moreover, the different strains are said to change their physiological and morphological characteristics in relatively short periods of time, a circumstance that would rob any attempt at classification of any except a slight historical interest. Even the recognition of group species, certainly not a very happy conception at best, is held to be futile for the same reasons. One might desire the author to have extended his observations on the tendency toward mutation, to include besides characteristics like color of thallus, spore color, or abundance of sporulation, in respect to which it is almost impossible to get any group of fungi to behave in a consistent way, possible significant changes in structure. As the direction of relation of the spiral sporogenous hyphae, for example, has been reported to be an invariable specific characteristic, it would have been interesting to learn whether or not this too is subject to change by mutation.

The volume contains an abundance of illustrations, including a large number of microphotographs of excellent quality, as well as four plates of colored figures very well executed and reproduced.—CHARLES DRECHSLER, *New York Botanic Gardens.*

Rocky Mountain flowers

Since the appearance of its earlier edition in 1914, none of the less technical books have proved as useful in becoming acquainted with the vegetation of the Rocky Mountains as Clements' *Rocky Mountain flowers.*[2] This is due in large measure to the drawings, and more especially to the attractive colored plates that are reproductions of water color sketches by Mrs. CLEMENTS. The twenty-five colored plates, together with a very simple descriptive text, have also been issued in a smaller volume[3] for the use of travelers, or to be employed as a souvenir of vacation days.

Among the notable features of the larger volume are a chart exhibiting the genetic relationship of plant families, a key to the families, and numerous keys to genera and species. More complete descriptions of species would be desirable, but could only be given by greatly enlarging the volume. The present edition is on thinner paper, and being bound in flexible leather covers, is very convenient as a pocket companion on mountain climbs.—GEO. D. FULLER.

Weeds of farm land

Miss BRENCHLEY[4] has published an interesting book on weeds of farm land. This discussion of farm weeds should be interesting to the practical man as affording an opportunity of comparison between the problems of the English and the American farmer. For the latter there may be practical hints and methods that may be applicable to his own fields. The ecologist will find more discussion of the fundamental problems of competition and succession than generally appears in weed manuals. The chapters on "Vitality of weed seeds," "Association with soils," "Association with crops," and "Grass land weeds" touch upon the relationship of plants to their environment and to one another, and seek for solutions of practical problems in the control of limiting factors. Other interesting chapters are those on "Parasitic weeds," "Poisonous weeds," "Uses of weeds," and "Popular and local names of weeds." The last topic is treated in detail, not less than 69 synonyms being given for *Galium Aparine*, 80 for *Orchis mascula*, 54 for *Senecio Jacobaea*, 35 for *Polygonum aviculare*, and 40 for *Ranunculus acris*. The illustrations suffer by comparison with those of similar American books.—GEO. D. FULLER.

---

[2] CLEMENTS, F. E., and CLEMENTS, EDITH S., Rocky Mountain flowers. 8vo. pp. 392. *pls. 47*. Field edition. New York: H. W. Wilson Co. 1920.

[3] CLEMENTS, EDITH S., Flowers of the mountain and plain. 8vo. pp. 79. *pls. 25*. New York: H. W. Wilson Co. 1920.

[4] BRENCHLEY, WINIFRED E., Weeds of farm land. 12mo. viii+239. *figs. 41*. London: Longmans Green & Co. 1920. $4.50.

NOTES FOR STUDENTS

Taxonomic notes.—BLAKE[5] has described a new genus (*Neomillspaughia*) of Polygonaceae, based on *Campderia paniculata* Donn. Sm., of Honduras. It includes another species from Yucatan.

PENNELL[6] has begun the publication of a list of genera of RAFINESQUE not recorded in *Index Kewensis*, although published in *Autikon Botanikon*. This first instalment presents 83 genera which should be included in any complete index. It is possible that some of these names should be in use.

YUNCKER[7] has published a very complete revision of *Cuscuta*, which is the first attack upon this difficult genus since ENGLEMANN'S monograph of 1859. The history and morphology of the genus are given, in addition to the taxonomic presentation. The monograph includes 54 species, 26 occurring in the United States, 33 in Mexico, and 7 in the West Indies. Of the 54 species and 42 varieties, 14 species and 16 varieties are new, and 32 species are figured for the first time. A full bibliography and index of collections are also included.

MISS DOIDGE[8] has published the results of her studies of South African Microthyriaceae, adding very materially to the knowledge of the group in that region. She recognizes 24 genera, including 50 species, 28 of which are described as new. Much the largest genus is *Asterina*, with 30 species, 14 of which are new. The remaining new species are distributed among 9 genera.

STANDLEY[9] has published a manual of the flora of Glacier National Park, especially for the benefit of the numerous visitors. The manual will be of use also elsewhere in the mountains of Idaho, Alberta, and British Columbia, and will be helpful in the Yellowstone National Park.

TRELEASE[10] has monographed the North American species of *Piper* belonging to the section OTTONIA. He recognizes 12 species, describing 8 of them as new.

The second contribution to the flora of Micronesia and Polynesia,[11] under the editorship of DIELS, includes 24 contributions by various investigators. The most extensive one (68 pp.) is by SCHLECHTER on the Orchidaceae

---

[5] BLAKE, S. F., *Neomillspaughia*, a new genus of Polygonaceae, with remarks on related genera. Bull. Torr. Bot. Club **48**:77–88. *pl. 1.* 1921.

[6] PENNELL, F. W., "Unrecorded" genera of RAFINESQUE. 1. Autikon Botanikon (1840). Bull. Torr. Bot. Club **48**:89–96. 1921.

[7] YUNCKER, T. G., Revision of the North American and West Indian species of *Cuscuta*. Univ. Ill. Biol. Monographs **6**:1–142. *pls. 13.* 1921.

[8] DOIDGE, ETHEL M., South African Microthyriaceae. Trans. Roy. Soc. S. Africa **8**:235–282. *pls. 13–19.* 1920.

[9] STANDLEY, PAUL C., Flora of Glacier National Park, Montana. Contrib. U.S. Nat. Herb. **22**:235–438. *pls. 33–52.* 1921.

[10] TRELEASE, W., North American Pipers of the section Ottonia. Amer. Jour. Bot. **8**:212–217. *pls. 5–8.* 1921.

[11] Beiträge zur Flora von Mikronesien und Polynesien. II. Engler's Bot. Jahrb. **65**:429–528. 1921.

of Micronesia. He recognizes 37 genera, one of which (*Rhynchophreatia*) is new, and describes 38 new species. We are only beginning to realize the wealth of orchids in the tropics.

HUGHES[12] has published a revision of the Australian species of *Stipa*, recognizing 40 species, 17 of which are described as new. This is in striking contrast with the 15 species recognized in the *Flora Australiensis*, especially since only 5 species of the 40 characterized are based on material unknown to BENTHAM.

The current numbers of *Notizblatt* (Bot. Gart. Berlin-Dahlem) contain numerous taxonomic contributions, dealing with the flora of South America, Africa, and the East Indies. The new genera described are as follows: *Tetradema* (Gesneriaceae) by SCHLECHTER (**7**:15–18. 1920), from the East Indies and the Philippines; *Peekelia* (Leguminosae) by HARMS (**7**:26, 27. 1920), from New Guinea; *Chelyocarpus* (Palmaceae) by DAMMER (**7**:44–51. 1921), from Brazil; *Paraphyadanthe* (Flacourtiaceae) by MILDBRAED (**7**:399–405. 1921), from Africa; *Cheilanthopsis* (Polypodiaceae) by HIERONYMUS (**7**:406–409. 1920), from Burma; *Afrolicania* (Rosaceae) by MILDBRAED (**7**:483–485. 1921), from Africa; *Neozenkerina* (Scrophulariaceae) by MILDBRAED (**7**:491–493. 1921), from Africa; *Stenodrepanum* (Leguminosae) by HARMS (**7**:400–501. 1921). KRÄNZLIN (**7**:412–451. 1920) also describes 44 new species of Orchidaceae from Columbia, this being only the first paper of a series.—J. M. C.

Origin of Hawaiian flora.—Because of its notable endemism, the flora of the Hawaiian Islands has always been of fascinating interest to plant geographers. CAMPBELL[13] in some recent studies of this flora regards the Hawaiian problem as the most important distributional problem that exists anywhere. HILLEBRAND, and perhaps most investigators, have held that the Hawaiian flora has always been isolated, the islands having been thrown up from great depths by volcanic action. Recent studies by PILSBRY on the Hawaiian land snails have shown noteworthy Malaysian affinities, and now CAMPBELL finds similar evidences from the plants. The liverworts and filmy ferns in particular are unsuited to long overseas transportation, and must have existed in Hawaii since it was connected with other lands. The relationship of these plants is much closer to the flora of Malaysia and Australasia than to America. Of 40 species of pteridophytes found elsewhere, 38 are common to Australasia or Malaysia, and only two are common to America. Fifty-one genera of spermatophytes are common to Australasia or Malaysia, and only six are common to America. The endemic genera are more closely related to Asia

---

[12] HUGHES, D. K., A revision of the Australian species of *Stipa*. Kew Bull. no. 1. pp. 30. 1921.

[13] CAMPBELL, D. H., The origin of the Hawaiian flora. Mem. Torr. Bot. Club **17**:90–96. 1918.

———, The derivation of the flora of Hawaii. Leland Stanford Junior Univ. Publ. I. pp. 34. 1919.

or the south Pacific than to America. The American elements that are present are accounted for partly through introduction by winds or migratory birds, and partly as a residue of once more widespread forms that are now extinct except in Hawaii and America. The absence of conifers may similarly be explained by extinction, if they were ever present, or by the absence of suitable soil conditions. The almost complete absence, for example, of granitic or calcareous soils might well explain certain absences. It is noted also that great ocean deeps separate Hawaii from America, whereas it is much shallower between Hawaii and the Orient. It is concluded, therefore, that the Hawaiian flora has been derived for the most part from the southern Pacific region, and that the Hawaiian Islands are a remnant of a northeastern extension of some large land mass, once connected closely with south Pacific lands.—H. C. COWLES.

Studies of cambium.—BAILEY,[14] in a third paper on cambium, has made what he calls a cytological "reconnaissance." In the preceding paper, reviewed in this journal,[15] he called attention to the size variations of cambial initials, and to the unusual opportunity offered by the cambium for the study of a number of fundamental cytological problems. In this preliminary study he has reached the following conclusions. The initials of the cambium, which may attain a length of more than 9000 μ, are uninucleate, and the "working distance" of their nuclei must extend in some cases for a distance of several thousand microns. The nucleo-cytoplasmic ratio may be relatively constant in ray initials, but varies enormously in fusiform initials. All the cambium initials of *Pinus Strobus* contain the diploid number of chromosomes. Small ray initials may contain as large chromosomes as adjacent fusiform initials with a volume 200–1000 times as large. Fusiform initials, which are frequently several hundred times as long as they are wide, divide longitudinally by an extraordinary extension of the cell plate. The various types of cell plate formation described by various cytologists are believed to be merely different phases or stages of a single general type of cytokinesis. These glimpses would seem to justify the writer in his belief that the cambium well deserves intensive cytological investigation.—J. M. C.

Economic plants of Philippines.—In an illustrated report BROWN[16] gives a series of descriptions of the indigenous food-producing plants of the Philippines. Many will be surprised to find the statement that the edible wild plants of these islands are less abundant, more inaccessible, and inferior in

---

[14] BAILEY, I. W., The cambium and its derivative tissues. III. A reconnaissance of cytological phenomena in the cambium. Amer. Jour. Bot. 7:417–434. *pls. 26–29.* 1920.

[15] BOT. GAZ. 71:408. 1921.

[16] BROWN, WM. H., Wild food plants of the Philippines. Phil. Dept. Agric. and Nat. Res., Bur. For. Bull. 21:1–165. *figs. 81.* 1920.

quality to those found in the United States. There are certain notable exceptions, however, as the pili nut (*Canarium luzonicum*), which is abundant and superior to the almond in quality, and the wild mango (*Mangifera caesia*), with its delicious flavor. Nuts, seeds, fleshy fruits, buds, leaves, roots, and tubers are included in the list, and the drawings and photographs used to represent them are of excellent quality.

A companion report by WEST and BROWN[17] deals with native resins and oil-producing plants, which are rather numerous. One difficulty in the utilization of the resins of many of the trees is to be found in the large number of species found in any particular area, making the number of individuals of any one species in any locality rather small. Several of the oil-producing plants give promise of good results under cultivation. In this report, also, the illustrations and descriptions give much botanical information.—GEO. D. FULLER.

Ecological research.—In his report of the work of the Carnegie Institution for 1920, Director MACDOUGAL[18] indicates the lines of research being followed by various members of his staff, and affords hints of results being attained. He has been measuring in detail the growth of certain trees and the accumulation of food material by the potato. CANNON and FREE have continued their investigations of the growth of roots as related to aeration. The factors affecting plants in new habitats have been under investigation by MACDOUGAL, and his results seem to show that species may be the more readily transferred from cool regions to warm, from montane regions to maritime, and from regions of climatic extremes to those of equable climates than the reverse. SHREVE reports progress in a soil temperature survey of the United States and Canada, in his investigations of the arid Avea Valley, and in his explorations of the Santa Lucia Mountains. Mrs. SHREVE has studied seasonal changes in the transpiration of *Encelia farinosa*, and VINSON and GRIFFIN have investigated the changing composition of Salton Sea water. The strand vegetation near Monterey, California, has been examined by COOPER, and stations and quadrats established for more exact studies of the associations and their controlling factors. Evaporation rates on the Monterey peninsula are decidedly less than in the oak and chaparral region east of Monterey, and this may account for the pine forests covering the former area.—GEO. D. FULLER.

Calcicoles.—In a discussion of plants found on soils supposed to be calcareous, SALISBURY[19] makes it clear that the problem of the limitation of the

---

[17] WEST, A. P., and BROWN, W. H., Philippine resins, gums, seed oils, and essential oils. Phil. Dept. Agric. and Nat. Res., Bur. For. Bull. **20**: 1–230. *figs.* 73. 1920.

[18] MACDOUGAL, D. T., Department of botanical research. Carn. Inst. Wash. Year Book for 1920. **19**: 49–81. 1921.

[19] SALISBURY, E. J., The significance of the calcicolous habit. Jour. Ecol. **8**: 202–215. 1920.

species to this substratum is by no means a simple one. In the first place, there is great need of more accurate data regarding the exact distribution of such "calcicoles" and of the exact nature and chemical reaction of the soils in which they are growing. As an example of the need of such precautions it is shown that "calcifuges" may and do occur on soils usually considered calcareous, but on account of leaching there is really no calcium in the soil in contact with the plant during its youthful and critical stages. It is further shown that complexity is added to the problem by the secondary characters usually accompanying calcareous soils, such as their comparative freedom from toxic products of decay, their usually low water-holding capacity, the more abundant development of their soil fauna, and the influence of calcium upon the absorption of other elements such as potassium.

The entire discussion is a thoughtful consideration of the various aspects of the problems concerned, and with the rather extensive bibliography is a good survey of the entire field.—GEO. D. FULLER.

Forest trees of Hokkaido, Japan.—Recognizing in the rapid changes taking place in Hokkaido a menace to the existence of its forests and its timber supplies, the government has appreciated the importance of a scientific knowledge of its trees as a basis for increased attention to forestry. As a result of the investigations thus prompted, there is being issued a most attractive set of beautifully colored plates, accompanied by descriptive text in Japanese and English.[20] The plates depict the foliage, flowers, fruit, buds, seeds, and seedling stages, one plate being devoted to each species. The three fascicles now issued include *Taxus cuspidata*, *Abies sachalinensis*, *A. Mayriana*, *A. Wilsonii*, *Picea Glehni*, *P. jezoensis*, *Larix dahurica*, *Pinus pentaphylla*, *P. pumila*, and *Thujopsis dolabrata*. The finished work will comprise not less than 85 species.—GEO. D. FULLER.

Notes on Conifers.—Two botanical memoirs by CHURCH[21] will be of interest to teachers of botany, especially those most concerned with morphology and forestry. These papers are used at Oxford in class work, making it unnecessary for the students to take lecture notes, and, at the same time, furnishing very complete outlines for laboratory work. Both papers lay emphasis upon features which can be seen without a compound microscope, although the microscope is used for some details of the life history. The first paper is

---

[20] MIYABE, KINGO, and KUDO, YUSHUN, Icones of the essential forest trees of Hokkaido. 10.5×15 inches. Sapporo. Pub. by the Hokkaido government. Fasc. 1.1–15. *pls 1–4*. 1920; Fasc. 2.16–26. *pls. 5–7*. 1920; Fasc. 3.27–37. *pls. 8–10* 1921.

[21] CHURCH, A. H., Elementary notes on Conifers. Botanical Memoirs. no. 8. Oxford University Press. pp. 32. 1920.

———, Form factors in Coniferae. Botanical Memoirs. no. 9. Oxford University Press. pp. 28. 1920.

more elementary and would be used by students who have had only a general course in botany. The second paper is more advanced and could be appreciated only by students who have some previous knowledge of Gymnosperms.—C. J. CHAMBERLAIN.

Indian Botanical Society.—A notable botanical movement in India is the recent organization of "The Indian Botanical Society," whose aims, constitution, and list of members have just been published for distribution. It is stated briefly to be "a society for uniting the botanists and promoting the botanical interests of India." A more detailed statement of aims is to improve the quality and content of botanical instruction, to encourage and promote research, to provide a central exchange, and to make available to members the scattered and insufficient botanical literature that reaches India. The president is WINFIELD DUDGEON of Ewing Christian College, Allahabad City, and the other officers, three of whom are Indians, represent other institutions. The society begins with 85 members, representing 10 provinces of India.—J. M. C.

African veld.—In a description of the vegetation of South Africa, POLE-EVANS[22] uses the term "veld" to include all the native vegetation ranging from a rich forest on the southeastern coast to a desert in the interior Karroo. He covers the ground as in a former article noted in this journal,[23] but with more emphasis on the economic resources and possibilities of each region. The nineteen divisions into which he divides the region possess rainfalls ranging from zero to 70 inches per annum, while the diversity in vegetation is correspondingly great. This diversity is made evident by excellent illustrations, as well as by lists of species and the enumeration of resources of timber, fibers, gums, and fruits in addition to the forage plants.—GEO. D. FULLER.

Embryogeny.—SOUÈGES,[24] in continuation of his numerous detailed studies of the embryogeny of various families of seed plants, has reported his results for *Urtica pilulifera*, *Senecio vulgaris*, four species of *Rumex*, and a species of *Rheum*. The details are too numerous to recite, but the excellent figures present the facts clearly for those using such data.—J. M. C.

---

[22] POLE-EVANS, I. B., The veld: its resources and dangers. So. African Jour. Sci. **17**:1–34. *figs. 56*. 1920.

[23] BOT. GAZ. **66**:539. 1918.

[24] SOUÈGES, RENE M., Embryogénie des Urticacées. Dévelopement de l'embryon chez *l'Urtica pilulifera*. Compt. Rend. **171**: no. 21. 1920.

———, Embryogénie des Composées. Les premiers stades du développement de l'embryon chez le *Senecio vulgaris*. Compt. Rend. **171**:254. 1920.

———, Embryogénie des Composées. Les dernier stades du développement de l'embryon chez le *Senecio vulgaris*. Compt. Rend. **171**:1920.

———, Recherches sur l'embryogénie des Polygonacées. Bull. Soc. Bot. France IV. **20**:1–11, 75–85. 1920.

MORPHOLOGY *of* GYMNOSPERMS

By JOHN M. COULTER *and* CHARLES J. CHAMBERLAIN

A revised edition of Coulter and Chamberlain's well-known work on *Morphology of Gymnosperms* is now offered, not only for the use of investigators, but for advanced students in this field.

Each of the seven great groups is presented in detail, and the final chapter discusses the problem of phylogeny and points out the evolutionary tendency. Although some corrections and additions occur in the presentation of all the groups, the most numerous changes will be found in the chapter on Cycadales, the group which has received the most attention since the publication of the former edition. The most important addition is to the Bibliography, 150 titles being added to the 484 titles of the former book. This list will put the student in touch with the work of the last seven years. The book is equipped with an index and appendixes.

"The most important general work on the gymnosperms which has ever appeared."—E. C. JEFFREY in *Science*.

478 pages, 462 illustrations, 8vo, cloth; $5.00, postpaid $5.20

The University of Chicago Press
Chicago - - - - - Illinois

POSITIONS OF ALL KINDS

Never was the demand so great for qualified teachers and specialists. For ten years we have given our time and energy to this work. Write for our *free* literature. State qualifications briefly.

Co-operative Instructors' Association
Marion - - - - Indiana

BOOKS ON NATURAL SCIENCE

Bought and Sold

Catalogues free on application

H. G. FIEDLER
401 West 47th Street - - NEW YORK

From the Cambridge University Press

THE GENUS IRIS

By WILLIAM RICKATSON DYKES

With 48 colored plates and 30 line drawings in the text

This magnificent work brings together the available information on all known species of Iris. The most striking feature of the book is the life-size colored plates, reproduced from originals drawn from living plants—making it a volume of remarkable beauty as well as of great scientific importance.

254 pages, demi folio, half morocco; price on request.

The University of Chicago Press
Chicago - - - - - Illinois

THE LIVING CYCADS

By CHARLES JOSEPH CHAMBERLAIN
Professor of Botany in the University of Chicago

This study includes investigations extending over fifteen years, that necessitated trips to Cuba, New Mexico, Australia, and Africa. The author studied all the genera and many of the species in the field, and preserved much material for later study in the laboratory.

In the first part of the book is given an account of the distribution, general appearance, and field conditions of the cycads, together with some of the experiences of an investigation involving much travel in distant and varied countries. In the second part is presented the life-history of the group based largely on the author's own observations in the field and laboratory. Part III is devoted to the evolution and phylogeny of the cycads, the opportunity for such a study being exceptionally favorable because the ancestry can be traced back through geological periods, and because the extinct predecessors of the cycads are the best known of the fossil plants.

xiv+172 pages, cloth; $1.50, postpaid $1.60

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO - - - - - - - ILLINOIS

FINE INKS AND ADHESIVES
For those who KNOW

Higgins'

- Drawing Inks
- Eternal Writing Ink
- Engrossing Ink
- Taurine Mucilage
- Photo Mounter Paste
- Drawing Board Paste
- Liquid Paste
- Office Paste
- Vegetable Glue, Etc.

Are the Finest and Best Inks and Adhesives

Emancipate yourself from the use of corrosive and ill-smelling inks and adhesives and adopt the Higgins Inks and Adhesives. They will be a revelation to you, they are so sweet, clean, well put up, and withal so efficient.

At Dealers Generally

CHAS. M. HIGGINS & CO., Mfrs.
Branches: Chicago, London
271 Ninth Street Brooklyn, N.Y.

Remington Portable

This handy, compact writing machine, latest addition to the famed Remington family, is especially designed for intimate, individual use. It has the Standard keyboard, fits in a case four inches high, turns out beautiful, clean-cut work, can be carried everywhere and used anywhere.

Every man, woman and child who has any writing to do, can accomplish more work in less time—and with more pleasure—with the help of this friendly little companion.

Price, with case, $60.00 in U.S.A.

Remington Typewriter Company
(Incorporated)
374 Broadway New York City

SPENCER MON-OBJECTIVE BINOCULAR MICROSCOPE No. 3

Interchangeable with a single microscope tube

Spencer Mon-objective Binocular No. 3. Completely equipped $227.50

Two Microscopes in One

This binocular body represents a departure from the stereotyped design of other makers, in which the ocular tubes are made parallel. In the Spencer the ocular tubes converge, which relieves all eyestrain and conforms to the position assumed by normal eyes in examining ordinary objects or in reading common print. With tubes thus arranged, it is unnecessary to acquire a new art in order to successfully use a binocular microscope.

Send for new Booklet M 9

SPENCER BUFFALO U.S.A.

SPENCER LENS COMPANY
Buffalo, New York

SPENCER BUFFALO U.S.A.